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Appendix III

Mobile Diesel-Fueled Engines: Appendix to the Diesel Risk Reduction Plan

September 2000

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I. PURPOSE

This report summarizes the need for further regulation of on- and off-road mobile diesel-fueled engines to reduce ambient diesel particulate matter (diesel PM) and the associated health risk. Proposed control measures to achieve those reductions are described, along with estimated emission reductions and costs per vehicle. Suggested non-regulatory strategies that may achieve additional reductions in emissions are also described.

II. ENGINE CATEGORIES

A. On-Road Engines

There are approximately 700,000 on-road diesel-fueled vehicles currently in use in California. Diesel-fueled, or compression-ignition, engines are used in every on-road vehicle category except for motorcycles, and include light- to heavy-duty trucks, school buses, urban buses, and passenger vehicles (Table 1). The majority of on-road diesel-fueled engines, however, are found in heavy-duty vehicles with a gross vehicle weight rating (GVWR) from 14,000 pounds GVWR and up. The reported heavy-duty vehicle population includes an adjustment to account for mileage by out-of-state registered vehicles that travel in California

The federal definition of a heavy-duty vehicle is any vehicle with a GVWR greater than 8,500 pounds. California's lower GVWR limit for heavy-duty vehicles is either greater than 8,500 pounds or greater than 14,000 pounds, depending on the model year [13 CCR § 1900(a)(9)]. For the purpose of this report, "heavy-duty vehicle" is used to refer to any vehicle with a GVWR greater than 8,500 pounds. The two categories of light heavy-duty trucks, from 8,501 to 14,000 pounds GVWR, comprise vehicles currently covered by emission standards for medium duty vehicles. For the weight classes above 14,000 pounds GVWR, heavy-duty vehicles are further subdivided into medium heavy-duty and heavy heavy-duty. The additional heavy-duty categories are school buses and urban transit buses. Larger motor homes would also be considered "heavy-duty."

The population of heavy-duty vehicles is predicted to increase on average by approximately 12 percent from 2000 to 2010 (Table 1). Medium heavy-duty vehicles are projected to increase by about 16 percent and heavy heavy-duty vehicles by about 10 percent. The proportionate increase is greater in the South Coast Air Basin, where the expected increase from 2000 to 2010 in heavy-duty vehicles is about 23 percent. Again, medium heavy-duty trucks are expected to increase faster than heavy heavy-duty trucks (27% versus 19%, respectively) in the South Coast Air Basin. Interestingly, the greatest population increase for any category, on a percentage basis, is expected to occur in diesel-fueled motor homes, which will almost double by 2010, from 1.2 to 2.4 percent of the diesel-fueled vehicle population statewide.

Table 1
On-Road: Categories and Population of Diesel-Fueled Vehicles (EMFAC2000)

		Statewide Population		SoCAB Population	
Category	**GVWR (lb.)**	**2000**	**2010**	**2000**	**2010**
Passenger Cars	all	111,430	41,630	43,050	16,160
Light-Duty Truck 1	up to 3,750	19,160	8,220	4,820	2,140
Light-Duty Truck 2	3,751-5,750	12,250	7,990	3,270	2,350
Medium-Duty Vehicle	5,751-8,500	134,870	117,230	28,050	25,960
MDV/Light Heavy-Duty Truck 1	8,501-10,000	24,380	28,450	8,040	10,620
MDV/Light Heavy-Duty Truck 2	10,001-14,000	34,190	35,170	12,000	13,670
Medium Heavy-Duty Truck	14,001-33,000	163,100	189,220	66,080	83,680
Heavy Heavy-Duty Truck	33,001 +	148,480	162,780	58,170	69,120
School Bus	all	21,250	25,950	7,820	9,500
Urban Bus	all	9,940	11,760	4,360	5,260
Motor Home	all	8,150	15,500	2,580	4,980
	Totals	**687,200**	**643,900**	**238,240**	**243,440**

"SoCAB" – South Coast Air Basin

Although the majority of diesel-fueled vehicles fall into one of the heavy-duty categories (54 % in 2000), Californians today drive considerable numbers of diesel-fueled passenger cars, light-duty trucks, and medium-duty vehicles. The majority of the diesel passenger cars and light-duty trucks, however, are greater than 15 years old and ARB staff expects that most of these will be removed from service over the next decade to be replaced with other, non-diesel vehicles. Thus, the statewide population of diesel-fueled passenger cars and light duty trucks is expected to decline by about 60 percent over the next decade. The population of medium-duty diesel-fueled vehicles is also expected to decline statewide, but by only about 13 percent over the next ten years.

B. Off-Road Vehicles and Equipment

There are approximately 550,000 off-road diesel-fueled vehicles and equipment currently in use in California (Table 2), two-thirds of which are categorized as agricultural or construction equipment. Many equipment types are classified as "portable," or equipment of 25 horsepower or greater that is designed to be carried or moved from one location to another. For the purpose of this report, "motive" is use to designate the bulk of off-road equipment and vehicles that are not otherwise classified as portable.

Diesel-fueled off-road engines comprise 138 individual off-road vehicle and equipment types aggregated into 17 categories. Engine sizes range from under 15 horsepower to over 10,000 horsepower. These equipment categories include aircraft, agriculture, airport ground support, construction and mining, commercial, industrial, logging, transportation refrigeration units, lawn and garden, pleasure craft, locomotives, and others (Table 2). For this report, however, aircraft engines are not included.

Table 2
Off-Road: Categories and Population of Diesel-Fueled Equipment

Category		Population	
		2000	**2010**
Agricultural	Total	199860	199860
	Motive	*195940*	*186330*
	Portable	*3920*	*3730*
Airport Ground Support	Total	1970	2440
	Motive	*1480*	*1830*
	Portable	*490*	*610*
Commercial	Total	53710	59460
	Motive	*17470*	*19330*
	Portable	*36240*	*40130*
Commercial Marine Vessel	Total	n/a	n/a
	Motive	*n/a*	*n/a*
	Portable	*n/a*	*n/a*
Construction & Mining	Total	168450	188110
	Motive	*164020*	*183160*
	Portable	*4430*	*4960*
Dredging	Total	130	130
	Motive	*0*	*0*
	Portable	*130*	*130*
Drilling	Total	1500	1500
	Motive	*0*	*0*
	Portable	*1500*	*1500*
Industrial	Total	12160	13360
	Motive	*12160*	*13360*
	Portable	*0*	*0*
Lawn & Garden	Total	44200	50650
	Motive	*44070*	*50500*
	Portable	*130*	*150*
Locomotive	Total	n/a	n/a
	Motive	*n/a*	*n/a*
	Portable	*n/a*	*n/a*
Logging	Total	2780	2780
	Motive	*2780*	*2780*
	Portable	*0*	*0*
Military Tactical Support	Total	2300	2300
	Motive	*0*	*0*
	Portable	*2300*	*2300*
Misc. Portable	Total	90	90
	Motive	*0*	*0*
	Portable	*90*	*90*
Pleasure Craft	Total	19700	19860
	Motive	*19700*	*19860*
	Portable	*0*	*0*
Transportation Refrigeration	Total	40610	44150
	Motive	*40610*	*44150*
	Portable	*0*	*0*
TOTALS	**GRAND TOTAL**	**547460**	**574900**
	MOTIVE	*498230*	*521300*
	PORTABLE	*49230*	*53600*

For all categories, except for commercial marine vessels and locomotives, engines are further classified by the following horsepower groups: ≤15, 16-25, 26-50, 51-120, 121-175, 176-250, 251-500, 501-750, 751-9999, >9999 hp. The statewide population of these off-road vehicle and equipment types is expected to increase by approximately five percent from 2000 to 2010 (Table 2).

Staff count activity rather than pieces of equipment to determine emissions for commercial marine vessels and locomotive operations, thus Table 2 does not include population figures for these two categories. The commercial marine vessel category includes U.S. and foreign registered ships, tugboats, crew and supply boats, fishing boats, ferries, and other commercial vessels. Yachts and other recreational boats are categorized as pleasure craft.

About nine percent of off-road equipment types are classified as portable equipment for the purposes of permitting. Portable engines are granted a "permit to operate" either under local air district rules or through registration with the ARB under the Portable Equipment Registration Program. Portable engines are therefore subject to permitting requirements for in-use engines in addition to the rules that apply to new off-road engines. Portable equipment is discussed in more detail in Appendix II.

III. EMISSION INVENTORY

The development of an emission inventory is a multi-agency effort, conducted through a public process in which input is solicited from various agencies, air quality management districts, engine manufacturers, and technical consultants. The Air Resources Board is responsible for the final statewide emissions inventory, which is maintained in an electronic database. The California Health and Safety Code (HSC) [§§ 39607 (b) & 39607.3] requires the Board to approve, at a public meeting, the emission inventory for criteria pollutants, including emissions from mobile, stationary, area-wide, and non-anthropogenic sources. The Board's initial approval, under HSC § 39607.3, was required no later than January 1, 1998 and subsequent updates are required at least every three years.

Table 3 provides a summary of diesel PM emissions from mobile engines for the decades from 1990 to 2020 based on the EMFAC2000 inventory model. The model includes the effects of implementation of existing regulations, which are discussed in Section IV. In general, emissions decline over the four decades because of the effects of these regulations. New engines are subject to more stringent PM standards, and thus emissions decline as older engines are replaced with new, complying engines. Additional details regarding the emission inventories for on- and off-road engines are provided in the following Sections A and B.

Table 3
Statewide Estimates of Diesel PM Emissions for 1990 through 2020

Year	On-Road Engines		Off-Road Engines[1]	
	Population	Diesel PM (tpy)	Population	Diesel PM (tpy)
1990	606,700	18,360	476,300	25,310
2000	687,200	7,500	498,200	18,545
2010	643,900	5,290	521,300	15,910
2020	610,200	4865	527,800	12,830

[1] Does not include portable engines, which are discussed in Appendix II.

A. On-Road Engines

Methodology. California's emission inventory for on-road vehicles is an estimate of the amounts and types of emitted pollutants. The current on-road motor vehicle emission inventory, EMFAC2000, represents more than ten years of effort on the part of ARB staff to refine and improve the accuracy of the inventory, as well as to resolve observed discrepancies between measured ambient emissions, modeled air quality estimates, and estimated emissions.

Details regarding the scientific basis for the model can be found in the document entitled "Public meeting to consider approval of revisions to the State's on-road motor vehicle emissions inventory," dated May 2000, and in the accompanying Technical Support Document. In short, data were collected from all relevant sources and analyzed, the model was developed and tested, and the public had the opportunity to interact with staff regarding the model. As with the previous model, EMFAC2000 has an adjustment to the emission inventory for on-road vehicles to account for mileage traveled within California by heavy-duty trucks registered out-of-state. The outcome is a much improved model that more accurately describes emissions from on-road motor vehicles in California.

Current Emissions

The estimated statewide 2000 diesel PM emissions from on-road diesel-fueled motor vehicles are about 7,500 tons per year (Table 4). The majority of the emissions are generated by two categories of vehicles, medium heavy-duty trucks (21%) and heavy heavy-duty trucks (66%). The next largest categories are passenger cars (3%) and medium-duty vehicles (3%). The remaining emissions (7%) are from light-duty trucks, light heavy-duty trucks, school buses, urban buses, and motor homes. The same pattern occurs for NOx emissions from diesel-fueled vehicles, with medium heavy-duty trucks and heavy heavy-duty trucks generating 89 percent of the NOx emissions from on-road diesel-fueled vehicles, although the next two largest categories for NOx emissions are light heavy-duty trucks (2%) and medium-duty vehicles (1%). On-road diesel-fueled vehicle emissions in the South Coast Air Basin are 38 percent of the statewide total for diesel PM and 40 percent of the statewide total for NOx emissions from diesel-fueled vehicles.

2010 Emissions

The estimated statewide 2010 diesel PM emissions from on-road diesel-fueled motor vehicles are about 5,200 tons per year, which is an overall 30 percent decline from 2000 (Table 4). For passenger cars, light-duty trucks, and medium-duty vehicles, the average decline in diesel PM emissions is 60 percent and is accounted for by the predicted population decrease in these categories over the decade and by the effects of existing regulations. For the heavy-duty vehicle categories, vehicle population is expected to increase by about 12 percent, yet existing regulations will still cause a 30 percent decline in diesel PM emissions. A slightly smaller overall decline in diesel PM emissions, 27 percent, is predicted for the South Coast Air Basin. Diesel PM emissions from buses and motor homes, however, are not predicted to decline over the next decade. Diesel PM emissions from motor homes are expected to increase by one-third from 2000 to 2010, corresponding to a 90 percent increase in the predicted motor home vehicle population.

Emissions of NOx from diesel-fueled vehicles are also expected to decline over the next decade by 34 percent statewide and 29 percent for the South Coast Air Basin. Again, emissions from motor homes are expected to increase, corresponding to an almost doubling of the predicted population (Tables 1 and 4).

Table 4
On-Road Inventory – Diesel-Fueled Vehicles

Category		PM (tons per year) 2000	PM (tons per year) 2010	NOx (tons per year) 2000	NOx (tons per year) 2010
Passenger Car	Statewide	241	66	2,484	877
n/a	*SoCAB*	*106*	*29*	*1,169*	*435*
Light-Duty Truck 1	Statewide	44	15	457	190
Up to 3,750 lbs. GVWR	*SoCAB*	*15*	*4*	*135*	*62*
Light-Duty Truck 2	Statewide	22	11	263	175
3,751-5,750 lbs. GVWR	*SoCAB*	*7*	*4*	*77*	*58*
Medium-Duty Vehicle	Statewide	219	124	3,152	2,597
5,751-8,500 lbs. GVWR	*SoCAB*	*47*	*29*	*694*	*636*
Light Heavy-Duty Truck 1	Statewide	37	26	1,903	1,289
8,501-10,000 lbs. GVWR	*SoCAB*	*11*	*7*	*636*	*478*
Light Heavy-Duty Truck 2	Statewide	58	33	3,021	1,702
10,001-14,000 lbs. GVWR	*SoCAB*	*18*	*11*	*1,048*	*650*
Medium Heavy-Duty Truck	Statewide	1,607	1,428	49,754	32,975
14,001-33,000 lbs. GVWR	*SoCAB*	*646*	*617*	*20,355*	*14,592*
Heavy Heavy-Duty Truck	Statewide	4,927	3,127	177,928	113,041
33,001 + lbs. GVWR	*SoCAB*	*1,881*	*1,267*	*68,956*	*47,515*
School Bus	Statewide	153	157	4,810	4,529
n/a	*SoCAB*	*40*	*40*	*2,520*	*2,400*
Urban Bus	Statewide	179	179	10,085	9,599
n/a	*SoCAB*	*91*	*80*	*4,752*	*4,639*
Motor Home	Statewide	15	22	562	588
n/a	*SoCAB*	*4*	*7*	*172*	*183*
TOTALS	**Total Statewide**	**7,502**	**5,288**	**254,419**	**167,562**
	Total SoCAB	*2,866*	*2,095*	*100,514*	*71,648*

"SoCAB" – South Coast Air Basin

B. Off-Road Vehicles and Equipment

Methodology: California's emission inventory for off-road engines and associated vehicles is an estimate of the amounts and types of pollutants emitted from the thousands of pieces of equipment types used in various applications, all of which are characterized as "off-road." The Board approved an initial statewide off-road inventory in December 1997. The new computer model for the estimation of off-road emissions inventory (OFFROAD) was not completed at that time, however, and the staff made the commitment to bring revised estimates before the Board for approval.

Staff has since provided updated emissions inventories for most of the categories of off-road engines or equipment. Updated population and other input data were obtained from a variety of authoritative sources and provided to the public for comment, along with the updated model. Further modifications to input data and the model were made based on input from interested persons before the inventories were presented to the Board for approval. Diesel-fueled engines and equipment were included in three of the recently approved inventories: (1) the small off-road engine (<25 hp) emission inventory, which was approved March 26, 1998 (ARB, March 1998); (2) the pleasure craft exhaust emission inventory, which was approved December 10, 1998 (ARB, November 1998); and (3) the off-road large compression-ignited engine emission (≥25 hp) inventory, which was approved January 27, 2000 (ARB, January 2000). Details on the methodology used to derive the off-road inventory can be found in each of the associated reports.

The off-road inventory and model represent the most up-to-date data available to the ARB and are a significant improvement over the inventory of diesel PM presented in the "Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant" Part A, Exposure Assessment (Table IV-1) (ARB 1998). For example, the OFFROAD model contains a more comprehensive list of equipment from a wider range of categories. Several other parameters, such as emission factors, growth, deterioration, and seasonal use, were modified, resulting in a higher inventory of emissions.

Emissions. Most off-road equipment categories include both gasoline- and diesel-fueled engines, with NOx and diesel PM emissions from diesel-fueled engines dominating. Over the next decade, existing regulations will result in a decline in diesel PM from off-road mobile sources statewide at the same time that the population is growing. The total statewide population of off-road equipment, not including locomotives and commercial marine vessels, is expected to grow by 5 percent from 2000 to 2010, from about 547,000 to 575,000 pieces of equipment. Over the same time period, emissions of diesel PM are expected to decline by about 15 percent, from 20,000 tons per year in 2000 to 17,000 tons per year in 2010 (Table 5). The decline in diesel PM emissions will take place as older, dirtier equipment is retired and replaced with newer, cleaner equipment required by existing regulations.

The following section provides additional detail on the emissions from motive off-road diesel-fueled engines and equipment, excluding portable equipment. Motive off-road diesel-fueled engines cause about 92 percent of the off-road diesel PM. Appendix II provides information on the inventory for equipment defined as "portable" and regulated either by the local air districts or the ARB under the Portable Engine and Equipment Registration program, which generate about 8 percent of the off-road diesel PM.

Table 5
Off-Road Inventory – Diesel-Fueled Vehicles & Equipment

Category		PM (tons per year)		NOx (tons per year)	
		2000	**2010**	**2000**	**2010**
Agricultural	Total	3,547	2,575	54,579	37,091
	SoCAB	*212*	*153*	*3,276*	*2,224*
Airport Ground Support	Total	113	102	1,479	1,319
	SoCAB	*58*	*51*	*785*	*698*
Commercial	Total	749	646	9,957	7,791
	SoCAB	*292*	*252*	*3,883*	*3,039*
Commercial Marine Vessel	Total	4,522	5,157	30,060	33,493
	SoCAB	*2,531*	*3,130*	*14,460*	*17,247*
Construction & Mining	Total	7,721	5,658	121,048	83,876
	SoCAB	*2,856*	*2,093*	*44,787*	*31,035*
Dredging	Total	18	11	380	259
	SoCAB	*1*	*0.4*	*15*	*10*
Drilling	Total	234	135	4,339	2,929
	SoCAB	*29*	*18*	*562*	*380*
Industrial	Total	573	497	6,699	4,986
	SoCAB	*281*	*245*	*3,284*	*2,444*
Lawn & Garden	Total	113	40	1,278	500
	SoCAB	*47*	*18*	*526*	*205*
Locomotive	Total	1,151	1,129	53,838	52,888
	SoCAB	*215*	*208*	*10,943*	*3,561*
Logging	Total	244	150	4,069	2,378
	SoCAB	*0*	*0*	*0*	*0*
Military Tactical Support	Total	29	22	519	243
	SoCAB	*4*	*4*	*66*	*44*
Misc. Portable	Total	3	3	47	33
	SoCAB	*1*	*1*	*11*	*7*
Pleasure Craft	Total	26	33	968	1,205
	SoCAB	*7*	*11*	*292*	*365*
Transportation Refrigeration	Total	946	851	9,336	7,210
	SoCAB	*351*	*314*	*3,455*	*2,666*
TOTALS	**Total Statewide**	**19,988**	**17,009**	**298,596**	**236,306**
	SoCAB	*6,885*	*6,498*	*86,345*	*64,017*

1. Current Emissions: Motive Off-Road

Staff estimates there are currently almost 500,000 pieces of motive off-road diesel-fueled equipment in California, plus commercial marine vessels and locomotives, generating about 18,500 tons per year of diesel PM (Table 6). Four off-road categories, dredging, drilling, military tactical support, and miscellaneous portable, contain only equipment classified as portable. Diesel PM emissions in 2000 from all portable engines, as discussed further in Appendix II, are about 1,400 tons per year.

As discussed in the next section on existing regulations, the Clean Air Act prohibits California and other states from regulating emissions from new engines used in construction and farming equipment of less than 175 horsepower and in new locomotives. These equipment types are termed “preempted.” Statewide, diesel PM emissions from motive diesel-fueled equipment in preempted categories, and including commercial marine vessels, are about 10,400 tons per year in 2000, which is 56 percent of the motive off-road inventory (Table 6). Although not preempted from regulating commercial marine vessels, California has worked with the U.S. EPA on nationwide regulations because of the difficulty of enforcement and ease with which many of these vessels can move to different ports to avoid regulation. ARB is also not preempted from regulating off-road engines that are not new, but the inventory does not distinguish between new and not-new engines at this time.

2. 2010 Emissions: Motive Off-Road

Over the next ten years, total diesel PM emissions from all motive off-road diesel-fueled sources are predicted to decline by about 14 percent, from 18,500 tons per year in 2000 to 16,000 tons per year in 2010 statewide (Table 6). Diesel PM emissions from all portable engines decline from about 1,400 tons per year to 1,100 tons per year by 2010. Existing regulations lead to these emission decreases as old engines are replaced with new, cleaner engines. Emission declines occur in every category except for the commercial marine vessel category, for which the model predicts diesel PM emissions to increase by about 14 percent over the decade, from about 4,500 tons per year in 2000 to 5,200 tons per year in 2010. Diesel PM emissions decline at a somewhat higher rate over the ten years from federally preempted equipment (17%) than from the nonpreempted equipment (12%). If the increasing emissions from commercial marine vessels are excluded, however, the remaining nonpreempted equipment diesel PM emissions are predicted to decline by 40 percent as of 2010.

Table 6
Off-Road: Diesel PM Emissions
By Preempt and Non-Preempt Categories

2000	**Particulate Matter Emissions (tons per year)**					
	Preempt			**Nonpreempt**		
Category	**Portable**	**Motive**	**Total**	**Portable**	**Motive**	**Total**
Agricultural	160	2,654	2,814	3	730	733
Airport GSE	-	-	-	33	80	113
Commercial	452	26	478	252	18	270
Comm. Marine	-	-	-	-	4,522	4,522
Construction	132	5,392	5,524	119	2,078	2,197
Dredging	-	-	-	18	-	18
Drilling	42	-	42	192	-	192
Industrial	4	240	244	-	329	329
Lawn & Garden	-	-	-	4	109	113
Locomotive	-	1,151	1,151	-	-	-
Logging	-	178	178	-	66	66
Military	22	-	22	7	-	7
Misc. Portable	2	-	2	1	-	1
Pleasure Craft	-	-	-	-	26	26
Trans. Refer	-	789	789	-	157	157
Totals	**814**	**10,430**	**11,244**	**629**	**8,115**	**8,744**
2010	**Particulate Matter Emissions (tons per year**					
	Preempt			**Nonpreempt**		
Category	**Portable**	**Motive**	**Total**	**Portable**	**Motive**	**Total**
Agricultural	124	2,075	2,199	-	376	376
Airport GSE	-	-	-	29	73	102
Commercial	413	29	442	197	7	204
Comm. Marine	-	-	-	-	5,157	5,157
Construction	106	4,321	4,427	62	1,169	1,231
Dredging	-	-	-	11	-	11
Drilling	33	-	33	102	-	102
Industrial	-	212	212	-	285	285
Lawn & Garden	-	-	-	-	40	40
Locomotive	-	1,129	1,129	-	-	-
Logging	-	117	117	-	33	33
Military	18	-	18	4	-	4
Misc. Portable	2	-	2	1	-	1
Pleasure Craft	-	-	-	-	33	33
Trans. Refer	-	705	705	-	146	146
Totals	**696**	**8,588**	**9,284**	**406**	**7,319**	**7,725**

IV. SUMMARY OF EXISTING REGULATIONS

California law grants the Air Resources Board authority to adopt statewide regulations affecting mobile sources. Local and regional authorities may regulate all other sources of air pollution. In addition, the Health & Safety Code section 40447.5(a) grants the South Coast Air Quality Management District authority to require fleets of 15 or more vehicles to purchase clean vehicles[1] when adding or replacing vehicles, authority which they have recently exercised.

The federal Clean Air Act grants California the ability to adopt and enforce rules for the control of emissions from mobile sources as long as the State standards are at least as protective as the applicable federal standards. In the Clean Air Act Amendments of 1990, however, California and other states are prohibited from adopting and enforcing emission control standards for two categories of new off-road engines or vehicles: (1) engines used in construction and farm equipment of less than 175 horsepower and (2) locomotives or locomotive engines.

The following existing measures that control diesel PM emissions are divided into federal measures, California measures, and local measures adopted by the South Coast Air Quality Management District. In addition to measures adopted as regulations, this section also lists and describes existing alternative strategies, which include incentives and voluntary agreements. The summaries are provided herein for informational purposes only; agency staff and the regulations should be consulted for more specific information and for compliance purposes.

A. Federal Measures

Federal rules that are the same as or less stringent than California rules are not discussed in detail here but are covered in the next section on state measures. For certain categories, such as large marine vessels, aircraft, and locomotives, national rules are required to fully control what is a national or international fleet. These categories are discussed below.

Commercial Marine Diesel [40 CFR Part 94]: The standards apply to new marine compression-ignition engines at or above 50 horsepower in commercial vessels. The engines are used for propulsion and auxiliary power in a variety of applications, including fishing boats, tug and towboats, dredgers, cargo vessels, and ocean-going ships. The standards are similar to the Tier 2 standards for land-based off-road compression-ignition engines and locomotives and vary with engine cylinder displacement and rated power (Table 7). Class 1 engines are generally derived from off-road configurations. Class 2 engines are similar to those used in locomotives. Standards for these engines are phased in from 2004 through 2007. These standards apply only to engines used in commercial vessels, not to engines used in recreational boats or pleasure craft. The U.S. EPA expects the marine diesel engine standards to

[1] ". . . methanol or other equivalently clean burning alternative fuel . . ."

result in a 24 percent reduction in NOx emissions and a 12 percent reduction in PM emissions nationwide in 2030.

The large international cargo ships that berth in California harbors and travel long distances close and parallel to the coast emit the majority of air pollutants from commercial marine vessels in California, about 60 percent. The federal rule does not cover Class 3 engines used in these ships but defers their control to international treaty through the International Maritime Organization, known as MARPOL Annex VI. The MARPOL Annex VI international emission standards for NOx are based on rated engine speed.

Table 7
Federal Marine Diesel Exhaust Emission Standards

Engine Category	Displacement (liters/cylinder)	Starting Date	NOx+HC g/bhp-hr	PM g/bhp-hr
1	Power ≥ 50 hp, displacement <0.9	2005	5.6	0.3
	0.9≤ displacement <1.2	2004	5.4	0.22
	1.2 ≤ displacement <2.5	2004	5.4	0.15
	2.5 ≤ displacement <5.0	2007	5.4	0.15
2	5.0 ≤ displacement <15	2007	5.8	0.2
	15 ≤ displacement <20, power < 4425 hp	2007	6.5	0.37
	15 ≤ displacement <20, power ≥ 4425 hp	2007	7.3	0.37
	20≤ displacement <25	2007	7.3	0.37
	25 ≤ displacement <30	2007	8.2	0.37

Locomotives and Locomotive Engines [40 CFR Part 92]: U.S. EPA adopted emission standards for NOx, hydrocarbons (HC), carbon monoxide, particulate matter, and smoke for newly manufactured and remanufactured locomotives and locomotive engines to take effect beginning in 2001 (Table 8). The first set of standards, Tier 0, apply to locomotives and engines originally manufactured from 1973 through 2001, whenever they are remanufactured in 2001 or later. The Tier 1 and 2 standards apply to locomotives and engines originally manufactured on or after January 1, 2002 and January 1, 2005, respectively. Tier 2 locomotives will be required to meet the applicable standards at the time of original manufacture and each subsequent remanufacture. All locomotives are required to comply with both line-haul and switch duty cycle standards, regardless of intended usage. U.S. EPA estimates that in 2040 PM emissions will be reduced by 46 percent compared to 1995 baseline emissions and NOx emissions will be reduced by almost 60 percent.

Table 8
Federal Locomotive Exhaust and Smoke Emission Standards

Tier and Duty-Cycle	NOx (g/bhp-hr)		PM (g/bhp-hr)		Smoke (Percent Opacity – Normalized)		
	Line-haul duty-cycle	Switch duty-cycle	Line-haul duty-cycle	Switch duty-cycle	Steady-State	30-sec Peak	3-sec Peak
Tier 0 1973-2001	9.5	14	0.6	0.72	30	40	50
Tier 1 2002-2004	7.4	11	0.45	0.54	25	40	50
Tier 2 2005 and later	5.5	8.1	0.2	0.24	20	40	50

Urban Bus Retrofit Rebuild Program [40 CFR Part 85]: The U.S. EPA's retrofit/rebuild program for urban buses was intended to reduce ambient levels of PM in urban areas. Retrofit and rebuild requirements apply to 1993 and earlier model year buses operating in metropolitan areas with 1980 populations of 750,000 or more when their engines are rebuilt or replaced. The requirements took effect nationwide as of January 2, 1995. California required new urban buses to meet a 0.10 g/bhp-hr standard in 1991, prior to the effective date of the federal 0.10 g/bhp-hr standard, thus the federal retrofit requirements only apply to 1990 and earlier model year engines in California.

Heavy-Duty Highway Engine and Vehicle Standards [40 CFR Part 86]: The U.S. EPA has adopted standards for on-highway heavy duty vehicles beginning in 1974. The most recent rulemaking, which is described in section B below, adopted more stringent standards that take effect beginning with the 2004 model year, and is based on a negotiated Statement of Principles between the U.S. EPA, ARB, and heavy-duty engine manufacturers.

Nonroad Diesel Engine Standards [40 CFR Part 89]: Following negotiations with stakeholders, the U.S. EPA, ARB, and members of the off-road[2] diesel engine industry signed a Statement of Principles calling for significantly more stringent standards for emissions of NOx, hydrocarbons, and diesel PM emissions from compression-ignition engines used in most land-based off-road equipment and some marine applications. The final rule, with which California's rule harmonizes, is discussed in more detail in section B below.

B. California Measures

Heavy-Duty Vehicle Inspection and Periodic Smoke Inspection Programs [HSC §§ 44011.6, 43701; 13 CCR §§ 2180 et seq.]: The Heavy-Duty Vehicle Inspection Program reduces excessive smoke emissions and tampering on gasoline- and diesel-fueled vehicles above 6000 pounds GVWR through inspections at California Highway Patrol inspection facilities and scales, at fleet yards, and in random roadside stops. Violators receive citations and are required to perform corrective actions. The

[2] California uses the term "off-road."

ARB resumed the Heavy-Duty Vehicle Inspection Program on June 1, 1998, after a hiatus of four and one-half years, with a revised snap acceleration test procedure.

The Periodic Smoke Inspection program, implemented in 1999, focuses on self-inspections of heavy-duty diesel vehicles by fleet owners (fleet being two or more vehicles). Owners are required to conduct annual inspections of their California-registered vehicles with engines over four years old for smoke opacity and make repairs to comply with the smoke opacity standards. Owners maintain records for two years, which ARB inspectors may review. The projected statewide combined emission benefits for the two inspection programs are reductions in diesel PM of 5.24 tpd statewide in 1999, declining to 3.19 tpd by 2010 as new engines result in fewer smoking engines on the road.

Heavy-Duty On-Road Vehicles [13 CCR §§ 1956.8 et seq., 1965, 2036, 2122]: Heavy-duty vehicle gaseous emissions were first regulated by California in 1969 and by the U.S. EPA in 1974. Over the years, more stringent emission standards have paralleled improvements in control technology. In summer 1995, the ARB, the U.S. EPA, and heavy-duty engine manufacturers signed an agreement for the same emission standards nationwide, and to review those standards in 1999. In October 1997, U.S. EPA adopted those national standards for engines, along with changes to the existing federal averaging, banking, and trading program, and to useful life and maintenance requirements for heavy-duty diesel engines. California amended its heavy-duty vehicle regulations to harmonize with the federal amendments in 1998 for implementation with the 2004 model year.

The amendments to existing California emission standards and test procedures were designed to harmonize as closely as possible with the federal program. As with the adopted federal requirements, the amendments include a NOx plus nonmethane hydrocarbon (NMHC) emission standard of 2.4 g/bhp-hr; or 2.5 g/bhp-hr with a 0.5 g/bhp-hr NMHC cap. Particulate matter standards, however, have not changed since the 1994 model year, as shown in Table 9.

Table 9
California Heavy-Duty Vehicle Engine Emission Standards, Beginning with the 1988 Model Year(1)
(grams per brake horsepower-hour)

Model Year	Gross Vehicle Weight (pounds)	Non-methane Hydrocarbons	Total HC	Carbon Monoxide	NOx	HC + NOx	PM
1988-1989	over 14,000	n/a	1.3	15.5	6.0	n/a	0.60
1990	over 14,000	1.2	1.3	15.5	6.0	n/a	0.60
1991-1993	over 14,000	1.2	1.3	15.5	5.0	n/a	0.25
1994-1997	over 14,000	1.2	1.3	15.5	5.0	n/a	0.10
1998-2003	over 14,000	1.2	1.3	15.5	4.0	n/a	0.10
2004-later	over 14,000	n/a	n/a	15.5	n/a	2.4 or 2.5 w/ 0.5 NMHC cap	0.10

(1) Does not include optional standards applicable to heavy-duty vehicles or urban bus engine standards. Standards are supplied for comparison purposes only.

Low Emission Vehicles [13 CCR § 1960.1 and others]: The ARB first adopted low emission vehicle (LEV) regulations in 1990 to cover the 1994 through 2003 model year light- and medium-duty vehicles. LEV II regulations, running from 2004 through 2010, were adopted in 1998. The major elements that impact diesel-fueled vehicles include extension of passenger car emission standards to heavier sport utility vehicles and pick-up truck with GRWR up to 8,500 pounds, which formerly has been regulated under less stringent emission standards; and new cleaner standards for a new medium-duty class, for vehicles with GVWR from 8,501 to 14,000 pounds. Vehicles in this category, which overlaps with the light heavy-duty vehicle category, will be subject to emission standards nearly as stringent as passenger car standards, although manufacturers have the option of certifying to the less stringent heavy-duty engine standards. Diesel-fueled vehicles up to 8,500 pounds GVWR are unlikely to be able to meet these lower chassis standards, thus preventing their sale in California.

Urban Buses and Public Transit Bus Fleets [13 CCR §§ 1956.1-1956.4, 1956.8]: California's public transit bus fleet rule was approved by the Air Resources Board on February 24, 2000. In this rule, diesel PM and NOx emissions from urban buses will be reduced through progressively more stringent standards and a program that encourages transit agencies to purchase or lease low-emission, alternative fuel buses (Table 10). Transit agencies are given the flexibility to choose between two compliance paths, either the diesel path or the alternative fuel path. Both paths include a PM retrofit phase-in requirement beginning in 2003, and includes a 0.01 g/bhp-hr PM standard, beginning in October 2002. Continued use of diesel fuel mandates that the operator uses low-sulfur fuel beginning July 1, 2002. In addition, transit agencies are required to purchase zero emission buses on a mandated schedule. The low emission bus engine standards, together with the zero emission bus purchase requirements, will reduce diesel PM emissions by 67 pounds per day and NOx by seven tons per day statewide by 2020.

Table 10
California Urban Transit Bus Fleet Rule Requirements and Emission Standards

Model Year	**"Diesel" Path**		**"Alternative-Fuel" Path**	
	NOx (g/bhp-hr)	**PM (g/bhp-hr)**	**NOx (g/bhp-hr)**	**PM (g/bhp-hr)**
2000	4[1]	0.05	2.5 optional[2]	0.05
Oct. 2002	2.5 (NOx+NMHC)	0.01	1.8 (NOx+NMHC) optional[2]	0.03
Oct. 2002	4.8 NOx fleet average		4.8 NOx fleet average	
2003-2009	Accelerated PM retrofit requirements[3] ≤ 15 ppm sulfur diesel fuel		PM retrofit requirements ≤ 15 ppm sulfur diesel fuel	
Jul. 2003	3 bus demos of ZEBs[4] (large fleets)			
2004[5]	0.50	0.01		
2007	0.20	0.01	0.2	0.01
2008	ZEBs:15% of new purchases (large fleets)			
2010	n/a		ZEBs:15% of new purchases (large fleets)	

(1) Shaded areas show existing requirements and optional emission standards
(2) Although transit agencies on the alternative-fuel path are not required to purchase engines certified to these optional standards, the staff expects that they will do so in order to qualify for incentive funding. At present, the only alternative-fuel engines available are certified to optional, lower-emission NOx standards.
(3) Transit agencies on the diesel path must meet the PM retrofit requirements at an accelerated rate and must complete all retrofits by 2007.
(4) Zero Emission Bus. A large fleet includes over 200 vehicles.
(5) In lieu of purchasing buses meeting the 2004 – 2006 emission standards, transit agencies on the diesel path may implement an alternative strategy that achieves greater NOx emission reductions. The alternative strategy must be approved by the ARB's Executive Officer.

Off-Road Compression-Ignition Engines [13 CCR §§ 2420 et seq.]: Exhaust emission standards for off-road heavy-duty compression-ignition engines become increasingly more stringent, based on the power produced by the engine and model year (Table 10). The off-road compression-ignition rule was the result of a negotiated process that resulted in the Off-Road Statement of Principles (SOP). California is preempted by federal statute from adopting emission standards for new off-road construction and agricultural equipment with engines less than 175 horsepower, thus a national rule was necessary to achieve emission reductions from that subset of engines. California's rule harmonizes with the federal program. Statewide diesel PM emission benefits, in conjunction with the federal rule, are 8.5 tons per day in 2010, of which 0.9 tons per day is from non-preempted equipment and 7.6 tons per day is from preempted equipment. In 2001, ARB and U.S. EPA plan to review the feasibility of the Tier 3 standards, and of the Tier 2 standards for engines rated under 37 kW (50 hp), after which Tier 3 PM matter standards would be proposed.

Table 11
Emission Standards for Off-Road Compression-Ignition Engines
(grams per brake horsepower-hour)

Maximum Rated Power	Tier	Model Year	NOx	NMHC+NOx	PM	Smoke (%)
hp<11	1	2000-2004		7.8	0.75	20/15/50*
	2	2005 +		5.6	0.60	
11≤hp<25	1	2000-2004		7.1	0.60	
	2	2005 +		5.6	0.60	
25≤hp<50	1	2000-2003		7.1	0.60	
	2	2004 +		5.6	0.45	
50≤hp<100	1	2000-2003	6.9			
	2	2004-2007		5.6	0.30	
	3	2008 +		3.5	tbd**	
100≤hp<175	1	2000-2002	6.9			
	2	2003-2006		4.9	0.22	
	3	2007 +		3	tbd	
175≤hp<300	1	1996-2002	6.9		0.40	
	2	2003-2005		4.9	0.15	
	3	2006 +		3	tbd	
300≤hp<600	1	1996-2000	6.9		0.40	
	2	2001-2005		4.8	0.15	
	3	2006 +		3	tbd	
600≤hp<750	1	1996-2001	6.9		0.40	
	2	2002-2005		4.8	0.15	
	3	2006 +		3	tbd	
hp>750	1	2000-2005	6.9		0.40	
	2	2006 +		4.8	0.15	

*Percentages apply to smoke opacity at acceleration/lug/peak modes; smoke opacity limits apply to all engines except: (1) single cylinder engines, (2) propulsion marine engines, and (3) constant speed engines.
**Tier 3 PM standards will be determined after the technology feasibility review in 2001.

The federal and California rules also include voluntary standards, to which manufacturers may opt to certify engines, earning the designation of "Blue Sky Series" low-emitting engines. Tier 3 emission levels, where applicable, were chosen as the best level for defining Blue Sky Series engines. This represents a reduction of approximately 40 percent beyond the Tier 2 NMHC + NOx levels. For PM emissions and for engines with no Tier 3 standards, a calculated level corresponding to a 40 percent reduction beyond Tier 2 levels will be used to qualify as a Blue Sky Series engine. Engines certified to these voluntary standards would be eligible for marketable credit programs. The manufacturer must declare at the time of certification whether it is certifying an engine family to an optional reduced-emission standard (that could subsequently be used in a marketable credits program).

Small Off-Road Engines (<25 hp) and Equipment [13 CCR §§ 2400 et seq.]: Beginning with the 1995 model year, California has applied progressively more stringent particulate matter emission standards to small off-road engines, including those that are diesel-fueled (Table 12). According to the small off-road inventory, 36% of the particulate matter emissions and 62% of the NOx emissions from small off-road engines come from diesel-fueled engines. With the signing and implementation of the compression-ignition off-road Statement of Principles, standards for small off-road engines have been folded into the heavy-duty CI standards such that future rulemaking will be coordinated along the entire range of off-road diesel-fueled engines.

Table 12
Comparison of Particulate Standards for Small Off-Road Engines
(grams per brake horsepower-hour)

Model Year	Applicability	PM	Applicability
1995-1999	all	0.90	Calendar year
2000-2004	<11 hp	0.75	Model year
2000-2004	11≤hp<25	0.60	Model year
2005 +	all	0.60	Model year

C. Local Measures (South Coast Air Quality Management District)

Clean On-Road Vehicles for Captive Fleets [Rule 1190 series]: Under California Health & Safety Code section 40447.5 the South Coast Air Quality Management District is given the authority to require public and private fleet operators with 15 or more vehicles to purchase clean-fueled vehicles at the time the operators are purchasing or replacing vehicles in their fleets. The SCAQMD is, therefore, implementing several rules to reduce diesel PM in the South Coast Air Basin:[3]

Rule 1191 - Light and Medium-Duty Public Fleet Vehicles, adopted June 16, 2000, applies to all government agencies located in the District, including federal, state, regional, county and city government departments and agencies, and any special districts such as water, air, sanitation, transit, and school districts, with 15 or more vehicles. Exempted are exempting emergency vehicles operated by local, state, or local law enforcement agencies; fire departments; paramedic and rescue vehicles; or heavy-duty on-road vehicles. Beginning January 1, 2001, public fleet operators of 15 or more vehicles may only procure vehicles that are certified by the ARB as equivalent low-emitting gasoline or alternative-fuel vehicles, when adding or replacing vehicles to their vehicle fleet.

Rule 1192 - Clean On-Road Transit Buses, adopted June 16, 2000, applies to those public transit fleets with 15 or more public transit vehicles or urban buses, operated by government agencies or by private entities under contract to government agencies, that provide passenger transportation services, including intra- and inter-city shuttle services. The rule does not apply to school transportation services, long-

[3] Potential emission benefits from these rules have not been calculated and are not reflected in the inventory.

distance services, paratransit vehicles, and transit vehicles used for non-public transportation. Beginning upon adoption of the rule, public transit operators with 100 or more vehicles are required to purchase alternative fuel transit vehicles when adding or replacing buses in the vehicle fleet. Public transit operators with 15 to 99 transit vehicles are required to comply beginning July 1, 2001.

Rule 1193 - Clean On-Road Residential and Commercial Refuse Collection Vehicles, adopted June 16, 2000, applies to refuse collection fleets with 15 or more curbside refuse collection vehicles, operated by government agencies or private entities. Fleet operators with 50 or more solid waste collection vehicles are required to purchase or lease only alternative-fuel heavy-duty vehicles when adding to or replacing curbside refuse collection or transfer vehicles to their fleet, beginning July 1, 2001. Refuse collection operators with 15-49 solid waste collection vehicles must comply beginning July 1, 2002. Exempted are test and evaluation vehicles and vehicles not used for the purpose of collecting or transferring waste.

Proposed Rule 1194 - Commercial Airport Ground Access would apply to all public and private fleet operators of 15 or more vehicles operated by the airport authority and to any other public or private fleet operators that transport passengers from commercial airports located in the District. Passenger transportation services at commercial airport terminals include taxi, limousine, passenger shuttles, and courtesy shuttle transportation provided by private vehicle leasing and rentals agencies and hotels. Beginning July 1, 2001, taxi and shuttle services would be required to purchase vehicles certified by the ARB that meet Ultra Low Emission Vehicle (ULEV), Super ULEV, or Zero Emission Vehicle emission standards when adding or replacing a vehicle to the fleet. Airport fleet operators providing courtesy shuttle services to the public in and out of airport terminals would be required to purchase alternative-fueled vehicles when adding or replacing vehicles as of July 1, 2001. *Set for adoption August 18, 2000*.

Proposed Rule 1195 - Clean On-Road School Buses *Requirements of Rule being developed.*

Proposed Rule 1196 - Clean On-Road Heavy-Duty Public Fleet Vehicles *Requirements of Rule being developed.*

Proposed Amended Rule 431.2 –Sulfur Content of Liquid Fuels would prohibit the sale of any diesel fuel with a sulfur content in excess of 15 ppm by weight on or after July 1, 2003, in the South Coast Air District. South Coast Air Quality Management District staff is proposing that the Executive Officer report to the Governing Board as to progress toward rule implementation by July 2002. This rule will require approval from ARB before it can be implemented by the South Coast AQMD. *Set for adoption September 15, 2000.*

Proposed Amended Rule 1186.1 – Street Sweeping Operations would apply to public and private fleets that own or lease 15 or more vehicles, including passenger cars, light-duty trucks, and medium- and heavy-duty on-road vehicles. Beginning July

1, 2002, for each additional purchase or lease of a sweeper, fleet owners would be required to purchase or lease either alternative-fueled street sweepers or, if the fleet operator can demonstrate technical unfeasibility, it can purchase diesel-fueled vehicles with approved emission control devices when adding or replacing vehicles. Governmental agencies that contract for sweeping services must contract for service with alternative-fuel sweepers or, if none are available, with diesel-fueled sweepers with approved control devices. *Set for adoption August 18, 2000*.

D. Non-Regulatory Strategies for Mobile Sources

Non-regulatory strategies include ARB programs that fall within its authority but are not implemented through regulation. These programs are usually accomplished through legislative action or voluntary agreement. Non-regulatory strategies include guidelines, memoranda of agreement (or understanding), and incentive programs that result in emission reductions beyond what is required by law, or at a faster pace than is required.

Carl Moyer Memorial Air Quality Standards Attainment Program (Carl Moyer Program) [HSC §§ 44275 et seq.]. The Carl Moyer Program, established in the 1998/1999 fiscal year, has received funding for three years. The Program has significantly reduced NOx and PM emissions from heavy-duty vehicles and equipment traditionally powered by diesel engines. The Carl Moyer Program Advisory Board (Advisory Board) has reviewed the program and recommended to the Legislature and the Governor that funding be continued for a multi-year program.

As originally established, the Carl Moyer Program was primarily intended as a NOx reduction program. The Advisory Board acknowledged that cancer-causing particulate matter emissions are a serious health concern throughout the state, and through its report to the Legislature and the Governor, recommended that the ARB staff address this public health issue within the Carl Moyer Program Guidelines.

With the first year's funding, the Carl Moyer Program reduced NOx emissions by approximately four tons per day. Additionally, it reduced particulate matter emissions statewide by approximately 100 pounds per day. These reductions were achieved even without specific program criteria to reduce particulate matter. These benefits have come from diesel engine to diesel engine repowers where older, less efficient diesel engines are replaced with new, more efficient, lower emitting diesel engines. Particulate matter benefits have also been achieved through alternative-fuel conversion projects. These projects generally provide the greatest emission reductions per engine and have the potential for longer-term emission reductions. The types of projects being funded include: purchase of new natural gas transit and school buses; purchase of new natural gas and dual-fuel trucks; purchase of electric forklifts instead of internal combustion forklifts; and replacement of old diesel engines with newer diesel engines in marine vessels, agricultural pumps, and other off-road equipment.

Locomotive Memorandum Of Understanding (MOU): Federal law preempts California from setting standards for new locomotives and new locomotive engines. In April 1998, as discussed previously, U.S. EPA adopted national emission standards applicable to remanufactured and new locomotives. Measure M14 of the California State Implementation Plan (SIP) for ozone called for a 67 percent reduction in NOx emissions within the South Coast Air Basin by 2010. In order to gain additional reductions over the federal rule and meet this obligation, California and the railroads negotiated a Memorandum of Understanding, which was signed in July 1998.

The MOU for locomotive emissions is a voluntary agreement between ARB, the Burlington, Northern, and Santa Fe Railway Company and the Union Pacific Railroad, which operate Class I freight railroads within the boundaries of the South Coast Air Basin non-attainment area. The agreement accelerates the introduction and use of cleaner, lower-emitting locomotives within the South Coast Air Basin.

V. RECOMMENDED MEASURES FOR REGULATORY ACTION

Diesel-fueled engines overwhelmingly dominate the large truck, bus, and off-road equipment markets, and have been growing in market share of the medium-duty and light heavy-duty vehicle market over the last decade. Manufacturers also plan to increase sales of diesel-fueled light-duty trucks and passenger cars nationwide over the next several years, although California's LEV II standards will slow diesel growth in these sectors in this state because of the stringency of the standards. Finally, some of the hybrid-electric vehicles in the research and development phase use diesel-fueled engines for power. Based on these market trends, lower new engine standards, along with low sulfur diesel fuel, are necessary to reduce exposure to diesel particulate emissions in California.

In addition to further tightening emission standards for new engines, emissions from existing compression-ignition engines must be lowered. Compression-ignition engines typically have useful lifetimes of 400,000 miles and longer. An engine is rebuilt, rather than replaced, when it reaches the end of its useful lifetime. Current regulations, except those applying to urban transit buses, allow the engine to be rebuilt to standards in effect at the time of original manufacture. Until recently, programs designed to ensure compliance with emissions in-use, such as on-board diagnostics, in-use compliance, and inspection and maintenance, have been primarily focused on gasoline-powered light- and medium-duty trucks and passenger vehicles. To reduce exposures to diesel PM, California needs to reduce emissions from existing vehicles and equipment, not just from new engines.

The measures proposed here comprise a comprehensive program to be implemented over the next decade in California to control emissions and reduce risk from exposure to diesel PM over the complete lifetime of diesel-fueled engines. At the same time, many of the proposed measures will also control and reduce emissions of NOx and other criteria and toxic air pollutants from compression-ignition engines. Table 12 provides a summary of the measures, expected emission reductions, and expected cost per unit for implementation. Most non-regulatory strategies are not included in Table 12 but are discussed in the text.

Table 13
Recommended Measures to Reduce Diesel PM From Mobile Sources

Measures	Proposed Implementation Date	Est. PM Reduction, tons per year		Est. NOx Reduction, tons per year		Est. Cost per Engine $
On-Road Measures		**2010**	**2020**	**2010**	**2020**	**2010**
Supplemental test procedures for HDV certification	2004	n/a	n/a	n/a	n/a	606
Lower emission standards for new HDV engines	2007	1,565* (646)	3,519 (1,592)	23,105 (9,578)	72,664 (32,880)	674-1,117
Control of emissions from existing engines (retrofit)	2001-2008	2,095 (866)	323 (146)	--**	--	1,900-9,500
Solid waste collection vehicles	2002					
Other public HDV fleets	2002					
Other public & private HDV fleets	2003-2008					
Control of HDV in-use emissions	2005	n/a		n/a		130-150
Off-Road Measures						
Lower emission standards for new engines	2006-2008	913 (292)	3,579 (1,132)	--#	--	1,327-1,770
Control of emissions from existing engines (retrofit)	2002-2008	5,968 (1,786)	1,505 (435)	--**	--	5,700-23,750
Public fleets	2002-2003					
Other off-road fleets	2006-2008					
Control of in-use emissions	2006-2008	n/a		n/a		tbd
PM standards for new diesel pleasure craft engines	2005	9 (3)	24 (8)	**	**	tbd
Non-Regulatory Strategies						
Federal locomotive retrofit program	2005	862 (161)	763 (150)	**	**	tbd
Federal commercial marine vessel retrofit program	2005	3,945 (2,396)	4,504 (2,955)	**	**	tbd

* Statewide emission reductions (South Coast Air Basin emission reductions)
**Retrofit measures specifically target PM reductions and not NOx
#Future NOx controls were adopted in January 2000, thus staff assumed no NOx reductions would be included with this measure.
n/a: not applicable
tbd: to be determined; data not available

A. On-Road Vehicles

The Air Resources Board has over 30 years of experience in regulating emissions from on-road mobile sources. The proposed measures described in this section reflect both past experience with regulating on-road mobile sources of air pollution and informed future expectations for technological solutions. New engines standards would be tightened to reduce emissions in the future. In the present time-frame, diesel PM emissions from existing vehicles would be reduced by the addition of aftertreatment technology to reduce diesel PM matter directly and through in-use compliance programs that will maintain the improvements achieved through cleaner new engine standards and retrofits.

Supplemental Test Procedures for Heavy-Duty Vehicle Certification

Description of the Proposed Measure

As a part of a required technology assessment of the 1997 heavy-duty vehicle standards, the U.S. EPA announced in an October 1999 notice of proposed rulemaking, supplemental strategies to further reduce emissions from heavy-duty vehicles beginning with the 2004 model year. The supplemental strategies include additional emission test procedures designed to ensure that engine exhaust emissions are controlled over the range of operating conditions. The strategies were modeled on the “pull-ahead” provisions of the heavy-duty diesel emissions consent decree between U.S. EPA and heavy-duty engine manufacturers[4] that had incorporated illegal emission control defeat algorithms into their engine control systems. The final rule, however, was not promulgated by U.S. EPA in time for a 2004 implementation and it is not clear that the relevant provisions of the consent decree will remain effective through the 2006 model year.

The “pull-ahead” provisions of the consent decree require manufacturers to produce engines that comply with the 2004 model year Federal Test Procedure Standards and the supplemental strategies beginning in October 2002 for 24 months of full compliance. Recently, the settling manufacturers have indicated that under certain circumstances the emission limits for the supplemental strategies cannot be met. The pull-ahead provisions allow extension of these requirements until 24 months of full compliance is attained. The U.S. EPA is therefore seeking to extend the pull-ahead provisions until the 2006 model year, after which more stringent new engine standards are proposed to take effect.

Staff believes that these supplemental strategies for model year 2004 and later heavy-duty diesel engines are feasible and should be implemented in California, if necessary because of changes to the consent decree. Together with the transient Federal Test Procedure, the goal of the proposed supplemental test requirements is to more closely model real world operations and conditions. The relevant test procedures include a supplemental steady-state test consistent with the European Union’s “EURO

[4] A parallel settlement agreement was negotiated by ARB and the engine manufacturers.

III ESC Test" with accompanying standards and Not-To-Exceed emission limits. The new standards would apply to certification, production line testing, and vehicles in actual use. This combination of tests is designed to ensure that engine emissions achieve the expected level of in-use emissions control over all expected operation regimes.

Feasibility

Seven of the largest heavy-duty diesel engine manufacturers will be implementing measures to reduce emissions beginning October 1, 2002, to meet the requirements of the heavy-duty diesel emissions consent decree.[5] The agreement requires those manufacturers to meet a 1.25 Not-To-Exceed limit, a 1.0 Euro III ESC limit, and to test engines over, and ultimately comply with, a load response test and limit. Given that the manufacturers have agreed to meet these standards in 2002, staff believes that this proposal is feasible for the industry as a whole by the 2004 model year. Should U.S. EPA identify an enforceable mechanism to assure compliance with these additional standards and procedures beyond 2004, adoption by California of this measure would not be required.

Probable emission control strategies include exhaust gas recirculation (EGR) and fuel injection rate-shaping. EGR is the recirculation of exhaust gas from a point in the engine's exhaust system to a point in the intake system. EGR reduces NOx emissions by up to 90 percent at light load and up to 60 percent at full load. EGR tends, however, to increase diesel PM emissions, a problem that can be controlled through proper system design. Fuel injection rate-shaping refers to precisely controlling the rate of fuel injected into the cylinder on a crank-angle by crank-angle resolution. It has been shown to simultaneously reduce NOx by 20 percent and PM by 50 percent under some conditions. Several manufacturers and fuel system suppliers have demonstrated fuel injection systems that can achieve effective rate shaping, and fuel injection rate-shaping is used to a limited extent today (U.S. EPA October 1999).

Estimated Emission Reduction

The proposal is expected to reduce diesel PM emissions through the reduction of secondary PM formed when NOx reacts with ammonia in the atmosphere to yield ammonium nitrate particulate and directly through the NTE limits. According to the U.S. EPA's draft Regulatory Impact Analysis (U.S. EPA, August 1999) for every 25 tons of NOx reduced, one ton of secondary PM is reduced. The emission benefit for California is unknown at this time.

Estimated Costs to Businesses, State and Local Agencies

Some heavy-duty diesel engine manufacturers would have increased costs from complying earlier than anticipated under U.S. EPA's proposed rule for engine certification. Seven of the largest manufacturers, representing about 90% of the market,

[5] The Heavy-Duty Diesel Emissions Settlement settled lawsuits brought by U.S. EPA and ARB alleging excess in-use emissions from defeat devices and algorithms.

however, have already agreed to comply with similar standards as of October 1, 2002, and thus would incur no additional costs from a California rule. The U.S. EPA estimated the costs of compliance with a similar rule to be $606 (weighted average, net present value) per vehicle for 2004 and 2005 model years, with costs declining as manufacturers gain experience with the technology (U.S. EPA August 1999). State and local agencies would be expected to incur additional costs, as passed on by manufacturers, to purchase vehicles. The ARB would have increased costs for monitoring compliance.

Potential Adverse Environmental Impacts

Potential adverse environmental impacts have not been identified at this time.

Lower Emission Standards for New Heavy-Duty Engines

Description of the Proposed Measure

Staff has determined that a PM emission standard of 0.01 g/bhp-hr for new heavy-duty engines to take effect for the 2007 model year is feasible. In addition, other emission standards could be reduced: NOx to 0.20 g/bhp-hr, and NMHC to 0.14 g/bhp-hr. The proposed PM standard represents a 90 percent reduction from the current PM standard of 0.10 g/bhp-hr, which has been in effect since the 1994 model year. Achieving the proposed PM standard will require the use of a highly efficient diesel particulate filter in conjunction with ultra-low-sulfur diesel fuel.

Feasibility

On May 17, 2000, the U.S. EPA released a Notice of Proposed Rulemaking that would adopt these proposed emission standards nationwide, judging them feasible beginning in 2007. The proposed standards have already been adopted by California for public transit buses. High-efficiency PM aftertreatment technology has been available for several years and has been applied with success in Europe and Asia. The proposed standard, along with more stringent standards proposed and being implemented in European and Asian countries, will spur additional research and development. In addition, research and development trends indicate that systems to significantly reduce both PM and NOx emissions will be commercially available and cost-effective within the proposed timeframe. Finally, very low-sulfur fuel (15 ppm cap), which will be required to protect the aftertreatment devices, should be available nationwide before 2007.

Estimate Emission Reductions

The estimated emission reductions from the proposed standards depend on projected population growth of heavy-duty vehicles and vehicle-miles traveled, PM emission factors, and engine deterioration rates. To model emission reductions, staff assumed that beginning January 1, 2007 all new engines conform to 0.01 g/bhp-hr PM standard and 25 percent of new engines comply with a 0.2 g/bhp-hr NOx standard. The NOx standard is assumed to phase in as follows: 50 percent of new engines sold will comply beginning January 1, 2008; 75 percent will comply January 1, 2009; and 100 percent will comply beginning January 1, 2010. This follows the U.S. EPA-proposed phase in schedule. A more rapid phase in period for NOx would reap greater emission reduction benefits. Based on the modeled assumption, staff estimates diesel PM will be reduced 1,565 tons per year in 2010 statewide, increasing to 3,519 tons per year in 2020 statewide when a greater proportion of the fleet will have turned over. Expected reductions in NOx emissions are 23,105 tons per year statewide in 2010, increasing to 72,664 tons per year statewide in 2020.

Estimated Costs to Businesses, State and Local Agencies

The costs of meeting the proposed 2007 model year emission standards estimated by U.S. EPA are summarized in Table 14 (U.S. EPA May 2000). The cost of a catalyzed diesel particulate filter, most effective option for PM control, is compared to new engine cost for each heavy-duty vehicle category. The cost of the diesel particulate filter includes both fixed costs, i.e., retooling, research and development, and certification; and variable costs, i.e., hardware, assembly, and markup. The average engine horsepowers in Table 14 were derived from the U.S. EPA certification database for the years 1999 and 2000. Diesel particulate filter operation requires the use of ultra-low sulfur fuel. The incremental cost of this fuel is expected to be less than $0.05 per gallon and is discussed further in Appendix IV. Each of these estimated incremental cost increases is expected to be less for 2012 and subsequent model year engines.

Table 14
On-Road Engines: Future (2007) Costs of Catalyzed Diesel Particulate Filter per Vehicle, Based on High Volume Production

Vehicle Class	**Light Heavy-Duty**	**Medium Heavy-Duty**	**Heavy Heavy-Duty**
Average Horsepower	**190**	**250**	**475**
Catalyzed DPF Cost	$674	$894	$1,117
New Engine Cost (comparison)	$8,527	$13,555	$23,722

Staff expect that manufacturers will pass along these costs to purchasers, which will increase costs to business owners and state and local agencies that purchase these vehicles. ARB will incur additional costs of monitoring compliance.

Potential Adverse Environmental Impacts

One technology that could be used to meet these standards, selective catalytic reduction (SCR) requires the use of urea to achieve emission reductions. SCR has been used to control NOx emissions from stationary sources for over 15 years and has been applied more recently to trucks, marine vessels, and locomotives. If this method is used to meet these new standards, there will be issues related to the so-called "ammonia slip," which is the release of excess ammonia in the exhaust.

Ammonia slip could form secondary particulate (nitrates) when released to the atmosphere. In order to eliminate ammonia slip, an oxidation catalyst can be installed downstream of the SCR unit, which would reduce ammonia slip by oxidizing most of the ammonia into harmless compounds. Staff is unable to quantify such impacts, however, and a more detailed study will be necessary to evaluate potential impacts. Adverse environmental impacts are not expected to occur for other technologies.

Control of Emissions From Existing On-Road Engines - Retrofit

<u>Description of the Proposed Measure</u>

While new engine standards can provide significant, long-term reductions in emissions as the fleet turns over, near-term emission reductions can only occur through programs that target the in-use fleet. The majority of heavy-duty diesel-fueled vehicles are operated in public or private commercial fleets. A retrofit program that requires fleet owners to retrofit their existing vehicles to reduce diesel PM could achieve significant reductions. At the same time, vehicles could also be retrofitted for NOx emissions reduction.

Staff believes that requiring existing heavy-duty vehicle owners to install aftertreatment devices would effectively reduce diesel PM, while simultaneously reducing NOx emissions, in the in-use fleet. The retrofit requirement could allow for different implementation dates, from 2001 through 2008, for different types of fleets. Retrofit requirements would be phased-in by vehicle application type and ownership of fleet vehicles. A PM retrofit requirement beginning January 1, 2003 has already been adopted for transit buses. The California 2000/2001 budget includes $50 million for a program aimed at replacing or retrofitting old school buses.

Fleets that ARB will address in the future include school buses, operated by school districts and private contractors; solid waste collection trucks, operated by cities, counties, special districts, and private contractors; other on-road heavy-duty publicly-owned fleets; and privately-owned heavy-duty fleets. The inventory of diesel-fueled passenger cars, light-duty trucks, and medium-duty vehicles will also be examined to determine if retrofits for these vehicles would be a cost-effective diesel PM reduction strategy.

Certain types of heavy-duty diesel-fueled vehicles could be exempted from the proposed PM retrofit requirements, such as heavy-duty trucks scheduled for retirement within two years of implementation and all alternative-fueled heavy duty vehicles. Vehicles exempted by statute include publicly owned emergency vehicles, including those operated by peace officers and fire fighters; vehicles owned by mosquito abatement, vector control, and pest abatement districts or agencies; and ambulances operated by private entities under contract to public agencies.

Feasibility

Several types of retrofit emission control technologies are available with varying levels of demonstrated effectiveness at reducing PM and NOx emissions. The list of available retrofit technologies includes diesel oxidation catalysts, diesel particulate filter systems, selective catalytic reduction, air enhancement technologies, such as electronic superchargers, and thermal management technologies, such as heat recuperators combined with oxidation catalysts. In some applications, two or more of these technologies can be combined to provide even greater emission control (MECA, March 2000). Technologies are discussed in more detail in Appendix IX.

The type of technology currently closest to commercialization with the maximum ability to reduce particulates to near zero is the diesel particulate filter. Diesel particulate filters have been demonstrated to reduce diesel PM by over 85%, depending on the operating cycle. Retrofit demonstration programs with diesel particulate filters began in the 1980s. In Europe, original equipment diesel vehicles with particulate filters are being offered commercially by Daimler-Benz and MAN on buses and Liebherr and Deutz on construction engines. Over 3,000 systems are in use in England, Scandinavia, and Germany. Oberland-Mangold had over 1000 systems in use on forklifts, construction site engines, stationary engines, passenger cars, and trucks. The company Linde + Still installs about 1,500 diesel particulate filters annually in forklifts. Finally, since 1990 the city of Zurich has operated 150 city buses and the city of Munich has operated 400 city buses with diesel particulate filter systems (Mayer 1998).

Pilot retrofit programs are currently in process in South Korea and Taiwan. In Taiwan, hundreds of buses have been equipped with different emission control technologies including catalysts and filters. In Korea, over 200 filter systems were evaluated on trucks and buses. In addition, Japan has recently stated its plan to require all diesel-fueled vehicles entering Tokyo to be equipped with diesel particulate filters (DieselNet 2000; Anonymous 2000). In the United States, the New York Metropolitan Transportation Authority has recently announced that it will install diesel particulate filters on every diesel bus in its fleet, over 3000 buses, by 2003, and will begin using ultra-low-sulfur fuel.

Estimated Emission Reduction

To estimate the emission impact for each phase, staff requires information on publicly- and privately-owned fleets, including the heavy-duty diesel vehicle population, model year distribution, and vehicle-miles-traveled distribution for each retrofit phase. Easily obtainable registration data from the Department of Motor Vehicles does not identify heavy duty vehicles by public or private ownership, and thus additional data collection will be required. For the purpose of this report, however, estimated emission reductions have been calculated for all existing heavy-duty engines for the years 2010 and 2020. Staff assumes that 90 percent of all eligible vehicles are retrofitted by 2010, using emission control devices that remove 85 percent of diesel PM. Staff estimate emission reductions of 2,095 tons per year statewide in 2010, declining to 323 tons per year statewide in 2020, as retrofitted vehicles are removed from the fleet and replaced with new engines. Diesel particulate filter retrofit is not expected to result in reductions in NOx emissions, although a retrofit rule will require that NOx emissions not be allowed to increase.

Approximate Cost To Businesses, State and Local Agencies

Businesses, State and local agencies will incur costs of retrofitting existing vehicles. While additional information must be collected prior to a formal rulemaking, the costs reported herein represent staff's best current estimate based on surveys of emission control equipment manufacturers, and assume low volume production and purchasing in the near term (Table 15). While vehicle owners may choose to use differing technologies to meet the retrofit requirement, this analysis will only cover the minimum technology requirement to reduce the maximum amount of PM emissions, i.e., the diesel particulate filter. The costs reported in Table 14 are based on $10 to $20 per horsepower for a catalyzed diesel particulate filter, as reported by the Manufacturers of Emission Controls Association (MECA, March 2000). Staff expects the actual cost as of the implementation date of this proposal to be somewhere in between these high and low estimates. The cost of ultra-low-sulfur fuel is discussed elsewhere in this report.

Table 15
On-Road Engines: Diesel Particulate Filter Costs for Retrofitting Current Vehicles

Vehicle Class **Average Horsepower**	**Light Heavy-Duty** **190**	**Medium Heavy-Duty** **250**	**Heavy Heavy-Duty** **475**
Capital Cost, DPF	$1,900-3,800	$2,500-5,000	$4,750-9,500

Because this proposal is expected to impact small business owners such as individual truck operators, staff recognizes that there is a benefit in establishing funding to assist those parties in order to implement the retrofit program smoothly. Public agencies will also incur costs, which would need to be borne by the state and local agencies. In addition, the ARB will have additional costs associated with certification of aftertreatment devices, compliance, and public outreach and education.

Potential Adverse Environmental Impacts

However, there are adverse environmental impacts associated with the application of catalyst-based DPFs. First, as is the case with most processes that incorporate catalytic oxidation, the formation of sulfates increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reductions in soluble organic fraction (SOF) emissions. Using diesel fuel with a very low sulfur content can minimize this effect.

In addition, the determination of whether or not a used DPF would be considered a “hazardous waste” at the end of its useful life depends on the material(s) used in the catalytic coating. DPFs can be manufactured with catalytic coatings such that the product would not be considered a hazardous waste at the end of its useful life.

DPFs are somewhat similar to automotive catalytic converters, and the California Department of Toxic Substances Control currently regulates used automotive catalytic converters as scrap metal as long as the catalyst material is left in the converter shell during collection and transport and the converters are going for recycling. The ash residue associated with cleaning a DPF would need to be tested before a hazardous waste determination could be made.

Control of In-Use Emissions for Heavy-Duty Vehicles

As new engine emission standards decline, manufacturers will need to adopt increasingly complex strategies to comply with the regulations. Electronic engine control, with associated sensors, engine design changes, and exhaust aftertreatment are all used to reduce emissions. With this increase in engine design complexity will come a corresponding increase in opportunities for malfunctions and premature failure of the emission control system. Staff therefore recommends adoption of a comprehensive program to control emissions from existing engines in-use. The following describes three strategies, in-use compliance testing, on-board diagnostics system, and an inspection and maintenance program that staff believes can be adopted for on-road heavy-duty diesel vehicles.

Description of the Proposed Measures

In-Use Compliance Testing. In-use testing programs are designed to monitor the emission levels of vehicles over their lifetime and to ensure that engines do not exceed their applicable certification emission standards. Under the current light-duty vehicle program, vehicles are selected and procured for testing. Emissions are measured and compared to certification levels. If enough vehicles of an engine family fail the testing, ARB can order a recall and manufacturers must fix the problem that caused the failure. Although ARB has authority for an in-use program for heavy-duty vehicles, currently it is not being implemented. Heavy-duty engines are certified separate from the vehicle, and thus in-use testing requires removal of the engine from the vehicle for testing on an engine dynamometer.

Staff believes, however, that the implementation of an in-use compliance program for heavy-duty diesel vehicles patterned after the light-duty compliance program could ensure low in-use diesel PM emissions. An in-use testing and recall program for heavy-duty vehicles that is based on chassis testing, rather than engine testing, would reduce the time and cost of conducting an in-use program.[6] A chassis test is an emission test conducted while the engine is in-place, on the vehicle, as

[6] In the State Implementation Plan, Measure M-17 recommends heavy-duty vehicle in-use testing based on a chassis test.

received by the testing facility. ARB is currently investigating development and feasibility of a chassis test program, which would include determining chassis test cycles and failure levels, taking into account the certification test and emission standards.

Current in-use testing programs for light-duty vehicles have proved highly effective at reducing excess emissions from the fleet. When ARB first began testing passenger vehicle engine families for in-use compliance, the staff recorded close to a 90 percent failure rate. The in-use testing program and associated recalls have provided manufacturers with the incentive to develop more robust emission control systems. As a result, manufacturers have reduced the in-use failure rate to less than 15 percent, even though staff select engine families for testing that are expected to experience failures. This dramatic improvement is evidence that a properly run in-use compliance program will dramatically reduce in-use emissions.

On-Board Diagnostics System. On-board diagnostics (OBD) systems are designed to reduce emissions throughout the life of an engine through monitoring emission-related parts and sensor outputs. Staff believes that expansion of OBD for heavy-duty vehicles could reduce in-use emissions. In passenger cars, light-duty trucks, and medium duty vehicles OBD systems monitor the components of the emission control system of the vehicle and notify the operator or an inspector of any malfunction through the use of a malfunction indicator light and stored computer codes (fault codes). This information not only informs the operator when there is a problem but also assists mechanics in identifying the cause of the problem.

ARB is taking the lead and is working closely with the U.S. EPA on the development and implementation of this program. Staff expects a heavy-duty OBD program to be structured closely after the current light- and medium-duty vehicle program. The heavy-duty program, which could be coordinated with implementation of the existing 2004 standards, will monitor emission-related parts such as the fuel metering system, aftertreatment devices, sensors, turbocharger, EGR, and misfire detection. Advances in technology and failure detection may also make it possible to reduce inspection and maintenance testing (discussed below) by combining the OBD system with a transponder. Such a system could not only notify the driver of an emission-related problem, but also be capable of sending this information to a centralized location for action.

Inspection and Maintenance Program. The ARB has had authority to perform tests and enforce limits on smoke opacity from diesel engines since the late 1980's. These in-use exhaust tests measure the opacity of the exhaust plume and are credited with PM reductions of approximately 39 percent by 2010. Since these tests are unable to measure NOx, the mass of fine particulates, and other air toxic compounds, however, a cost-effective alternate method of measurement needs to be developed.

Measure M-17 of the State Implementation Plan calls for incorporation of NOx screening as a part of the Heavy-Duty Vehicle Inspection and Periodic Smoke Inspection Programs. At the same time, staff believes that heavy-duty vehicles could be held to lower diesel PM standards, including a standard of no-detectable visible smoke emissions for newer engines. Currently, owners are subject to enforcement action when visible smoke meets or exceeds 70 percent opacity for pre-1991 engines and 40 percent or greater opacity for 1991 and newer engines. Since June 1998, the monthly average failure rate has varied between four and nine percent, with an overall average of 7.8 percent (ARB, May 2000).

A new test procedure for heavy-duty diesel vehicles could be similar to an in-use compliance test discussed above. The vehicle would be placed on a chassis dynamometer and emission levels would be measured directly from the exhaust stack or tailpipe. A smog check-type program could be operated similarly to smog check for passenger cars or tied through a voluntary program to the on-board diagnostics (OBD) system. With OBD equipped vehicles, the system could be configured to send out a low power signal indicating the system status. California Highway Patrol-operated weigh stations, which already are used for safety and smoke opacity inspection, could receive the low-power signal. If the signal indicates a properly functioning pollution-control system, the test would be waived. If the signal indicates a malfunction, the vehicle would be stopped for a chassis-based inspection. Vehicles not equipped with the ability to send the system status to the receiver, or vehicles on which the transponder is not activated, would be subject to annual or biannual pollution control system inspections.

<u>Feasibility</u>

In-Use Compliance Testing. A heavy-duty in-use compliance program would likely be structured after the current light- and medium-duty programs, which utilize chassis-based test procedures, allowing staff to rapidly determine compliance with applicable standards. Currently, heavy-duty diesel vehicle engines are certified using an engine test. In order to verify the emission levels of these engines in-use, the engine must be removed from the vehicle and installed on a stationary engine dynamometer. An owner would need to be provided a monetary incentive to compensate for the loss of vehicle usage during in-use testing or a new engine provided to replace the one that is removed. Staff estimates that testing an engine family (ten engines) could cost $300,000 to $700,000. A chassis-based test procedure, therefore, will be necessary in order to implement a large-scale, cost-effective in-use compliance program.

On-Board Diagnostics System. On-board diagnostic systems have been successfully used in light- and medium-duty applications. Medium-duty diesel-fueled vehicles have been required to use on-board diagnostics since the 1997 model year in California. Staff anticipates the same approach used for light- and medium-duty vehicles will be directly transferable to heavy-duty applications.

One of the key components of gasoline vehicle OBD systems is the oxygen sensor, which monitors and controls conditions for the catalyst. The analogous component for a diesel engine would be a NOx sensor. A NOx sensor with the necessary sensitivity and durability is not yet currently commercially available. There are, however, at least two manufacturers currently working on this issue that may bring commercially viable products to the market in the necessary timeframe. Given the available lead time and technology concerns, implementation of OBD for heavy-duty vehicles is expected to be feasible and effective.

Inspection and Maintenance Program. As with in-use compliance testing, the feasibility of an inspection and maintenance program is tied to the development and adoption of a chassis-based test that can be done in an acceptable amount of time, such as 15-25 minutes. An acceptable program would be quick, relatively inexpensive, and not require a huge new infrastructure for implementation. Staff will be exploring these issues but believes that these conditions can be met.

Estimated Emission Reduction

In-use emissions control programs are designed to ensure that the emission reductions expected from new engine and retrofit measures are realized, thus staff has not estimated emission reductions specifically from the programs proposed herein.

Approximate Cost To Businesses, State and Local Agencies

A provision for an in-use compliance program for heavy-duty diesel engines is currently included in the present regulations. The ARB anticipates developing a chassis test to allow for lower cost in-use compliance testing. This would reduce the overall cost of an in-use test program by eliminating the expense of removing the engine from the vehicle to perform an engine-based test. Testing costs may be borne by the State, and the cost of recall would be borne by manufacturers and passed on to consumers through higher vehicle or engine costs.

Because most new diesel engines on the market are currently equipped with most of the required sensors and computer controls necessary for an OBD system, staff estimates the cost of upgrading their present control package to include an OBD system should be approximately $30 - $50 per engine. This includes the cost of upgrading the current capacity of their present systems as well as the programming costs associated with OBD and is similar to that estimated for converting light-duty OBD vehicles to OBD II systems. Staff does recognize that the cost of adding an OBD system will be higher for those manufacturers who do not presently employ advanced computer-controlled systems. Staff has not yet determined the exact cost to monitor heavy-duty diesel aftertreatment devices, or to measure NOx directly. The necessary equipment to monitor NOx emissions and aftertreatment devices, however, should cost less than $100, for a total per vehicle cost of $130 to $150 (Table 16).

Table 16
On-Road Engines: Heavy-Duty OBD Estimated Costs

Item	Cost
CPU upgrade and necessary programming	$30-50
Additional sensors (NOx + Aftertreatment)	$100
Total estimated costs	***$130 -$150***

The cost for inspection and maintenance programs varies considerably depending on the scenario or test procedure used. For vehicle owners who are part of a voluntary transponder-equipped on-board diagnostics system, the cost could be a minimal annual fee. For older vehicles and those that are not participating in the voluntary transponder program, the cost of “smog-check-type” testing could be as high as $100 - $200 per vehicle per test. Staff requires additional data, however, to more accurately estimate costs. State and local agencies would be subject to the same costs as businesses. The ARB would incur additional costs to administer the program, which may be offset by the elimination of the Periodic Smoke Inspection Program.

Potential Adverse Environmental Impacts

The program is designed to ensure the emission levels of these engines remain at or below the adopted emission standards. For this reason, there should be little or no adverse environmental impacts associated with these measures.

B. Off-Road Vehicles and Equipment

Virtually all technologies or control strategies that can be applied to on-road diesel engines can also be applied to off-road diesel engines, although the effectiveness of those strategies may vary considerably because of the different nature of off-road operation. From an administrative standpoint, the most significant difference from on-road vehicles is that, with the exception of engines registered under the portable engine registration program, off-road engines and vehicles are not registered by the state. Thus, there are only limited mechanisms, such as warranty registration and local permits, with which to ensure the application of various in-use strategies, such as inspection and maintenance programs, in-use compliance testing or mandatory retrofitting of older equipment.

Functionally, off-road vehicles and equipment vary widely in application, from chainsaws to road graders, and in size, from less than one hp to over 10,000 hp. Measures to reduce engine emissions, therefore, require more research and time for implementation. The ARB staff are currently involved in a technology review that will provide additional information regarding feasibility of emission controls for off-road vehicles and equipment. As with on-road vehicles, the following measures proposed for off-road equipment and vehicles range from new engine standards to retrofits and in-use compliance strategies and reflect both past experience with regulating off-road mobile sources of air pollution and informed future expectations for technological solutions.

Lower Emission Standards for New Off-Road Engines

Description of the Proposed Measure

The recent national emissions standards for Off-Road Compression-Ignition[7] Engines that were adopted by both the U.S. EPA and the ARB consist of a tiered structure of emission limits based on engine power. The Tier 1 standards were implemented in 1996, while the Tier 2 standards are being implemented at the present or in the extreme near term. Both the Tier 1 and Tier 2 standards include limits on PM. The development of Tier 3 PM standards for engines between 50 hp and 750 hp is a task that ARB and U.S. EPA committed to as part of the Off-Road Statement of Principles (SOP). The two agencies are currently funding a contract with Southwest Research Institute to assess the capabilities of Tier 3 technology. That work will be used to support the 2001 technology review, also required under the SOP.

Although the work mentioned above does not include consideration of the use of aftertreatment devices, the staff believes that the Tier 3 PM standards should be based on the use of ultra-low-sulfur diesel fuel and a highly-effective diesel particulate filter along with on-board diagnostics systems to ensure proper operation. These strategies are projected to result in approximately 85 to 90 percent reduction of engine-out particulate matter emissions. At this time, staff estimates that new engines greater than 50 horsepower could be certified at a PM level of 0.02 g/bhp-hr (0.02 g/bhp-hr) (Table 17). Smaller engines and equipment will require additional work to develop and package an effective aftertreatment device that can fit within the space constraints.

Table 17
Off-Road Engines: Proposed Standards Based on Aftertreatment

Maximum Rated Power (hp)	Implementation (model year)	PM grams/brake horsepower-hour
hp<11	2008 and later	0.30
11≤hp<25	2008 and later	0.30
25≤hp<50	2007 and later	0.22
50≤hp<100	2007 and later	0.02
100≤hp<175	2007 and later	0.02
175≤hp<300	2006 and later	0.02
300≤hp<600	2006 and later	0.02
600≤hp≤750	2006 and later	0.02
hp>750	2006 and later	0.02

[7] Compression-ignition engines use diesel fuel.

Feasibility

The feasibility of this measure is dependent mostly on the availability of very low-sulfur fuel for off-road equipment and vehicles. A confounding factor is the federal preemption of authority to regulate new construction and farm equipment below 175 horsepower and new locomotives. These factors make it vital for the ARB to convince the U.S. EPA to set standards equivalent to the California standards and to similarly adopt ultra-low-sulfur fuel nationwide. The majority of larger off-road engines are equipped with electronic controls, so implementation of an on-board diagnostics requirement would be relatively easy, particularly for those engines with on-road counterparts.

If the U.S. EPA does not pursue the use of aftertreatment for the national Tier 3 standard, two courses of action present themselves. The first would be unilateral California implementation of aftertreatment-based Tier 3 standards. Unfortunately, because only the U.S. EPA may control emissions from new construction and farm equipment below 175 horsepower, a California-only regulation would cover a relatively smaller percentage of the new vehicles and equipment. A California-only regulation, therefore, is likely to prove more expensive on a per-engine basis and result in much lower emission reduction benefits than if the U.S. EPA also requires such standards.

The second course of action would be for ARB to adopt an aggressive aftertreatment retrofit program to ensure that an equal level of control is achieved from the engines not subject to the preemption. A retrofit program primarily targeted at public-owned and leased off-road vehicles is discussed below.

Estimated Emission Reduction

The emission inventories for 2010 and 2020 were estimated using the assumptions that all previously adopted emission standards remain in effect and durability requirements remain the same as adopted, and that NOx levels would not be affected by this measure. The already adopted Tier 3 off-road standards contain NOx standards, which are reflected in the emissions inventory baseline. Using these assumptions, staff calculated the emissions benefit from this proposal to be a reduction in diesel PM of 913 tons per year statewide in 2010, increasing to 3,579 tons per year statewide in 2020.

Approximate Cost To Businesses, State and Local Agencies

The major costs to businesses would include the increased costs of new hardware, maintenance, and ultra-low-sulfur fuel. Because the use of diesel particulate filters would allow engine manufacturers to calibrate engines with less concern about engine-out emissions, staff expects better performance with no fuel consumption increase. The cost estimates are based on the same sources as noted for on-road engines, and assume that those of-road engines would be equipped in the same time-frame. The on- and off-road engines are substantially similar, so both sets of engines should be able to take advantage of the high production volume. Off-road applications, however, would require extra research and development resources for possible equipment modification. Staff has estimated the equipment modification costs using the information contained in the regulatory impact analysis conducted by U.S. EPA for their off-road diesel rule (U.S. EPA, August 1998). The engine power ranges shown in Table 18 were selected to facilitate comparison with on-road costs. For on-road engines, the cost of an on-board diagnostics system is approximately $150. Thus, staff has assumed the same cost for a comparable OBD system for off-road equipment and vehicles.

Table 18
Off-Road Engines: Future Diesel Particulate Filter and OBD Costs Based on High Volume Production

Average Horsepower	190	250	475
Diesel particulate filter	$1,177	$1,397	$1,620
OBD System	$150	$150	$150
New Engine Costs (comparison)	$8,527	$13,555	$23,722

In addition to these costs, vehicle owners will incur incremental costs for very low-sulfur fuel and maintenance costs of the new hardware. Staff requires additional information to determine these life-cycle operating costs for off-road equipment and vehicles. The costs to State and local agencies would be the same as those experienced by businesses: increased costs for new hardware, maintenance, and ultra-low-sulfur fuel. The ARB will incur additional costs for regulatory development and ensuring compliance.

Potential Adverse Environmental Impacts

This proposed measure would benefit California's environment and reduce the public's exposure to the toxic diesel PM after implementation. Reductions in HC and CO are also anticipated. However, there are adverse environmental impacts associated with the application of catalyst-based DPFs. First, as is the case with most processes that incorporate catalytic oxidation, the formation of sulfates increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reductions in soluble organic fraction (SOF) emissions. Using diesel fuel with a very low sulfur content can minimize this effect.

In addition, the determination of whether or not a used DPF would be considered a "hazardous waste" at the end of its useful life depends on the material(s) used in the catalytic coating. DPFs can be manufactured with catalytic coatings such that the product would not be considered a hazardous waste at the end of its useful life.

DPFs are somewhat similar to automotive catalytic converters, and the California Department of Toxic Substances Control currently regulates used automotive catalytic converters as scrap metal as long as the catalyst material is left in the converter shell during collection and transport and the converters are going for recycling. The ash residue associated with cleaning a DPF would need to be tested before a hazardous waste determination could be made.

Control of Emissions from Existing Off-Road Engines - Retrofit

Description of the Proposed Measure

The long lifetime of diesel engines, particularly at the higher power ratings, requires a comprehensive control strategy to control existing engines to complement the development of new engine controls. A retrofit requirement is an obvious strategy, but one that must be carefully crafted to minimize any effect on the engine or on the equipment's ability to carry out its task. The most effective aftertreatment device for PM reduction is the diesel particulate filter, which is presently applicable to engines above 50 horsepower, unless technology becomes available that could package a diesel particulate filter for the smaller equipment and engines. A likely timeframe for privately-owned vehicles would be concurrent with the availability of very low-sulfur fuel in 2006. For publicly-owned or -contracted fleets, however, a phased-in implementation beginning in 2002 would be feasible.

Feasibility

Diesel particulate filters have been commercially retrofitted to off-road equipment since 1986. The types of equipment that have been retrofitted include mining equipment, material handling equipment, forklifts, street sweepers, and utility vehicles (MECA 2000). Over 2,500 diesel particulate filter systems are in operation worldwide; some of the systems have been operated for over 15,000 hours or over five years and are still in use. Existing off-road engines that are retrofitted with diesel particulate filters could achieve the same percentage reduction as new engines, approximately 85 percent assuming very low-sulfur fuel is available, although from a higher initial level of emissions.

Retrofit programs could be implemented using a variety of approaches, such as requiring local permitting agencies to ensure that retrofits are performed prior to the granting of permits. Another approach could require large state construction contracts to include a retrofit requirement as a contract condition. Finally, a retrofit rule for off-road could apply specifically to publicly-owned and –contracted fleets. While an off-road retrofit program is certainly feasible, its effectiveness may be less than optimum without a statewide registration program. This is because it would be difficult to track certain types of retrofitted off-road equipment, thereby hampering ARB's ability to directly enforce the retrofit installation. It may make sense, therefore, to propose a registration requirement in California for off-road equipment.

Estimated Emission Reduction

Almost all engines greater than 50 horsepower, other than portable engines, which would be subject to separate conditions, would be rebuilt or retrofitted to achieve an 85 percent reduction in diesel PM emissions. In order to calculate emission benefits, staff assumed that 90 percent of all eligible engines,[8] are retrofitted by 2010, using emission control devises that remove 85 percent of diesel PM. Staff estimate diesel PM would be reduced by 5,968 tons per year statewide in 2010, and by 1,505 tons per year statewide in 2020. These figures do not include the potential emission benefits of retrofitting locomotives and commercial marine vessels, which are discussed under non-regulatory strategies below.

Approximate Cost To Businesses, State and Local Agencies

The costs to vehicle owners of retrofit would consist of the hardware and installation costs at rebuild, subsequent maintenance costs, and the incremental cost of very low-sulfur fuel, which is required to maintain aftertreatment device operation. Very low-sulfur fuel is expected to cost 5 cents per gallon more than the present fuel. The cost to retrofit the diesel particulate filters is expected to be higher than the cost of incorporating the same equipment on new engines. Retrofitting with aftertreatment devices will not have been included in initial engine designs, nor will most owners be able to take advantage of high volume purchasing. The estimate given here does not assume any savings from retrofit systems sharing any components, such as the muffler, with the systems intended for new engines (Table 19).

Table 19
Off-Road Engines: Current Cost for Retrofit

Horsepower	**190**	***250***	**475**
Diesel Particulate Filter	$5,700-9,500	$8,250-13,750	$13,500-23,750

In addition to these costs, vehicle owners will incur incremental costs of very low-sulfur fuel and maintenance costs of the new hardware. Staff requires additional information to determine these life-cycle operating costs for off-road equipment and vehicles. Costs to State and local agencies would be similar to those incurred by businesses, consisting of the cost of retrofitting existing equipment at rebuild, subsequent maintenance costs, and the increased cost of very low-sulfur fuel. If the State creates a registration program, there would be administrative costs that could be offset by registration fees. ARB will incur costs from rule development, equipment certification, program management, and enforcement.

[8] Excluding portable equipment engines, which are covered in Appendix II.

Potential Adverse Environmental Impacts

This proposed measure would benefit California's environment and reduce the public's exposure to the toxic diesel PM after implementation. Reductions in HC and CO are also anticipated. However, there are adverse environmental impacts associated with the application of catalyst-based DPFs. First, as is the case with most processes that incorporate catalytic oxidation, the formation of sulfates increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reductions in soluble organic fraction (SOF) emissions. Using diesel fuel with a very low sulfur content can minimize this effect.

In addition, the determination of whether or not a used DPF would be considered a "hazardous waste" at the end of its useful life depends on the material(s) used in the catalytic coating. DPFs can be manufactured with catalytic coatings such that the product would not be considered a hazardous waste at the end of its useful life.

DPFs are somewhat similar to automotive catalytic converters, and the California Department of Toxic Substances Control currently regulates used automotive catalytic converters as scrap metal as long as the catalyst material is left in the converter shell during collection and transport and the converters are going for recycling. The ash residue associated with cleaning a DPF would need to be tested before a hazardous waste determination could be made.

Control of In-Use Emissions for Off-Road Vehicles and Equipment

Description of Proposed Control Measure

For off-road vehicles and equipment, staff proposes to modify the off-road in-use compliance testing program. Although in-use compliance testing is currently in place for off-road diesel engines, the existing program is limited to engine testing, rather than chassis or equipment testing. This hampers testing greatly by increasing the cost. Staff proposes that a simplified compliance assessment test be developed. The compliance assessment test should be an on-site test that can be correlated in some way to the certification test. Ideally, such a test should take 30 minutes to less than half a day to conduct to minimize the costs of taking a vehicle or piece of equipment out of service.

Feasibility

An in-use compliance program is not, strictly speaking, a control strategy, as much as it is a means of ensuring that the chosen control strategies remain effective over the lifetime of the engine or equipment. Typically, the ARB sends a letter to a vehicle owner notifying them that their vehicle has been selected for a voluntary testing program. If the vehicle owner chooses to participate, he or she is provided with a substitute vehicle while their vehicle is being tested. The difficulty involved in implementing this strategy for off-road engines includes the fact that off-road equipment tends to be specialized. For example, it would be difficult and expensive to provide a substitute for earth-moving equipment to an end-user in order to test his equipment, which is in constant use. Without a replacement piece of equipment, the down time encountered would provide a serious disincentive for owners or operators to participate in the program, hindering the ARB's ability to test a representative sample of similar equipment.

The current regulations for off-road compression-ignition engines include provisions for in-use compliance testing on an engine, not equipment, basis. The program allows for the identification in advance of purchase of the engines and applications that will be tested. This allows the engine manufacturer to retain an unused engine to be installed when the in-use engine is removed for testing. This approach, while providing some enforcement capability, is lacking in the element of surprise, and would allow a manufacturer to cut corners on the engine families that have not been selected. Full effectiveness of an in-use compliance program can be achieved if registration is required and engine manufacturers are assigned recall responsibility, as they are with on-road engines. A compliance test could possibly be developed based on the power take-off or hydraulic systems of many off-road vehicles or equipment.

Estimated Emission Reduction

In-use compliance programs are a means of ensuring that the chosen control strategies remain effective over the lifetime of the engine or equipment. Thus the emissions reductions attributable to this program can be divided into (i) direct reductions due to detection of failing systems, which will be similar to those experienced in on-road testing, and (ii) indirect reductions due to the deterrent effect of the program, for which the changes in compliance margin will be similar to those experienced in on-road certification. Staff have not estimated separate emission benefits from an off-road in-use program. Although those benefits could be substantial, they are presently assumed to be included in the estimated benefits from new engine standards and the retrofit measure.

Approximate Cost To Businesses, State and Local Agencies

Staff does not have an estimate of the cost of an in-use compliance assessment program to the end user, but expects that the cost will be small relative to the cost of the engine. Staff requires additional data to determine these costs. Manufacturers could incur additional costs of corrective action (i.e., recall) if an engine family failed testing.

The ARB would incur costs to implement the program. Staff estimates a per engine cost of $33,000 to $70,000, which includes the costs for engine replacement, an incentive to the owner, removal of the engine, installation and set-up of the engine for testing, the emission tests, and shipping. If ARB implements a simplified compliance assessment test, as described above, staff expects that per engine costs could be reduced to less than $20,000. Owners would not need to be provided with a new engine, and installation and shipping costs would therefore be eliminated. The cost of an incentive for testing could also be drastically reduced, provided the time necessary for the test is reduced to less than a full day.

Potential Adverse Environmental Impacts

No potential adverse environmental impacts have been identified for this measure to date. However, a more detailed evaluation of potential adverse environmental impacts will be done during the development of the specific control measures.

Particulate Matter Standards for New Diesel Pleasure Craft Engines

Description of the Proposed Control Measure

In 1999, the Air Resources Board adopted regulations for emission standards and test procedures for new 2001 and later spark-ignition marine outboard and personal watercraft engines. The rule did not cover diesel-fueled, or compression-ignition, inboard or auxiliary engines used in pleasure craft. Furthermore, the 1999 standards did not set PM emissions, but focused on hydrocarbon and oxides of nitrogen emissions. The adopted off-road compression-ignition rule, however, does cover marine engines less than 50 horsepower.

Staff suggests, therefore, that a diesel PM standard for new pleasure craft compression-ignition engines is necessary. The proposed implementation date would be 2005, with an initial target reduction of diesel PM by 25 percent overall or more by 2010. A NOx standard would also be proposed, and will be a part of any proposed rulemaking for recreational marine engines. Engines to which the rule would apply are inboards and auxiliary engines used for power generation and propulsion in recreational marine vessels, such as yachts and sailboats. The inventory of diesel PM emissions from this category, while small, is expected to increase by about 28 percent from 2000 to 2010, and 57 percent from 2000 to 2020, mainly due to growth in the population.

Feasibility

Control technology is expected to be available and feasible as the diesel-fueled engines used in pleasure craft are similar to on-road engines. These PM standards do not envision aftertreatment technology. Manufacturers would, therefore, be able to use the same control technology as has been developed and demonstrated for on-road engines, although the off-road retrofit program, discussed earlier, may be applied to existing pleasure craft engines.

Estimated Emission Reduction

Staff estimates the diesel PM emissions could be reduced, statewide, by 25 percent in 2010 by reducing the per engine emissions by approximately 65 percent beginning in 2005. As there is presently no diesel PM standard for these engines, the reduction was calculated based on the present exhaust emission factor of 0.34 grams per brake-horsepower hour. Staff estimates that a diesel PM standard between 0.1 and 0.15 grams per brake-horsepower hour would be necessary to achieve a 25 percent reduction in 2010. Maintaining the same engine emission standard for the next decade would result in a 60 percent reduction in 2020 emissions. Since most of the emissions are generated on summer weekends, the emissions benefit would be greater on a per day basis when adjusted by usage. The expected diesel PM emission reductions are 9 tons per year in 2010 and 24 tons per year in 2020.

<u>Approximate Cost To Businesses, State and Local Agencies</u>

Although staff expects that the costs of implementation of this measure to be similar to those for on-road engines, staff requires additional data to calculate costs. A diesel PM standard alone is unlikely to increase engine costs significantly as manufacturers could reduce diesel PM by engine retuning. A standard that reduces NOx simultaneously with diesel PM, however, is likely to increase the cost of the engine. As with on-road engines, the costs would include costs of engine redesign, hardware, operating and maintenance costs. ARB does not expect that implementation of a diesel PM standard alone will require aftertreatment devices, thus the incremental cost of very low-sulfur fuel may not be incurred.

<u>Potential Adverse Environmental Impacts</u>

No potential adverse environmental impacts have been identified for this measure to date. However, a more detailed evaluation of potential adverse environmental impacts will be done during the development of the specific control measures.

C. Non-Regulatory Strategies for Mobile Sources

Non-regulatory strategies are those actions for which ARB has authority to adopt guidelines, voluntary memoranda of understanding (or agreement), or incentive programs that are not regulations. An example of this would be the Carl Moyer Program Guidelines, which were developed through a public process and approved by the Board, but which were not adopted into regulation. A non-regulatory strategy, as discussed herein, could also be an activity for which ARB does not presently have authority, but which it may seek authority through legislative action. In addition, non-regulatory strategies could involve programs adopted and implemented by local air districts. No estimated emission reductions and costs have been calculated for these strategies for this report, although this information is discussed. Emission reductions and costs, however, would be estimated before any particular strategy is implemented.

Transportation Control Measures – Idling Restrictions

A technical advisory group created by legislation (AB 2595, 1988), developed initial guidelines in 1990 for reducing emissions from truck operations. Many of the transportation control measure concepts in these guidelines are still feasible and viable today. The advisory group included ARB, other transportation and air quality related agencies, and trucking industry representatives. The advisory group recommended and ranked measures based on feasibility, ease of implementation, cost effectiveness, and air quality benefit. The guidelines include truck idling restrictions, freight consolidation centers, time-of-day restrictions, and pricing measures, in descending order of ranking. Of these, truck idling restrictions are proposed to be feasible at this time.

Description of the Proposed Strategy

Idling restrictions limit the amount of time heavy-duty vehicle engines are allowed to operate while not performing useful work, e.g., moving the vehicle or operating essential equipment. Limiting idling would reduce ambient emissions and reduce public exposure (especially for truck and facility operators) to diesel toxics. It would also reduce fuel consumption and engine wear. An effective strategy must include compelling information to educate vehicle operators about the need to, and benefits of, limiting idling time.

Many heavy-duty truck operators allow their engines to remain idling while they are waiting to access facilities to make deliveries or pick-ups. Idling is common in areas of high truck activity, such as port facilities, rail yards, business parks, canneries, industrial parks, retail centers, construction sites, and truck stops. Many drivers allow their engines to idle out of habit or the misconception that heavy-duty diesel vehicles still require extended time to warm up and cool down. This, however, is no longer the case with modern engines.

Heavy-duty truck idling could be limited to a maximum time period, except under certain circumstances. The maximum time period would be set by start and idle emission analysis and practical trucking industry concerns. Stricter limits could be required in areas accessible to the general public, such as schools and shopping centers. Prohibiting school bus idling at school facilities could be an initial regulatory action. A companion measure would require, or incentivize, the installation of electrical outlets at truck and bus terminals to allow for sleeper berth use and cabin heating and air conditioning.

Options for implementation include a voluntary, education-based approach or a regulatory strategy that could involve: ARB adoption of a statewide truck idling regulation; local air district adoption of truck idling regulations, assisted by a model rule developed by ARB, or legislation amending the Health and Safety Code to restrict truck idling. Implementation should also include a program to gain the cooperation of facilities where truck idling occurs to support and better ensure compliance with idling restrictions.

Feasibility

The feasibility of implementing idling restrictions would be affected by costs and human nature. The costs to the state and local air districts of enforcing idling restrictions could be high, requiring additional staff to conduct inspections and monitor compliance at truck stops and by each truck owner. Alternately, if staff emphasizes the education approach, the cost would be somewhat lower. Gaining the cooperation of facilities where truck idling occurs to ensure compliance with the law will be challenging, requiring education and outreach activities at many locations throughout the state. Finally, ARB will have to extend its education and outreach activities into other states to notify out-of-state owners of vehicles that operate within California.

Estimated Emission Reduction

Potential emission reductions from this strategy could be estimated in-house through an analysis of current truck activity studies, with second-by-second geographic information system data, and truck idling and trip-end emission factors. Estimate emission reductions, however, were not calculated for this report.

Approximate Cost To Businesses, State and Local Agencies

The 1990 Advisory Group suggested that the savings to vehicle owners would offset the costs, and thus there would be no cost to businesses. Savings would accrue from reduced engine wear, increased engine life, and reduced fuel costs from decreased idling. The costs include an increased replacement frequency of the starter system and battery from increased starts, and the cost of electricity-adaptable air conditioning and heating units, if sleeper cab use is included in the idling restriction. In addition to costs to vehicle owners, owners of truck stops would incur the cost of installing electric outlets and implementing a procedure to charge truck owners for electricity used.

There are several categories of costs to state and local agencies. First, ARB and local air districts would incur additional costs for enforcement. Second, ARB and local air districts would incur costs associated with education for truck drivers, trucking facilities, and truck stops. Finally, the State of California could provide public funding to provide incentives for installing electrical outlets at truck stops.

Potential Adverse Environmental Impacts

No adverse environmental impacts have been identified at this time.

Retrofit for Emergency Vehicles

Description of the Proposed Strategy

Publicly-owned emergency vehicles, including those operated by peace officers, fire fighters, and paramedics, are exempt from requirements for pollution control devices. Also exempt are vehicles owned by mosquito abatement districts, vector control, and pest abatement districts or agencies, and ambulances operated by private entities under contract to public agencies. Because many of these districts and agencies operate heavy-duty, diesel-fueled vehicles, staff proposes to negotiate voluntary agreements with public agencies and districts for retrofitting these vehicles with diesel particulate filters and to work with manufacturers to assure that new emergency vehicles are equipped with modern, state-of-the art pollution control equipment.

Feasibility

The major issue affecting feasibility would be the cost of retrofitting vehicles with pollution control devices. Staff would attempt to identify funds that could be used to retrofit engines wherever retrofit devices could be installed without impairing the life-saving function of the vehicles. Staff would also work with agencies and districts to identify incentive funds that could be used to pay the incremental costs above the cost of purchase of the uncontrolled technology.

A secondary feasibility issue concerns the impact of emission control technology on the performance of the vehicle. In the past this was a valid concern. Today, however, manufacturers have long since developed technologies that control pollution with little or no effect on engine performance. Staff would, however, review this issue with respect to the specialized vehicles used by the exempt categories.

Estimated Emission Reduction

Current diesel particulate filter technology achieves 85 percent or better control of diesel PM. Staff, however, lacks the data necessary at this time to calculate estimated emission reductions. Staff requires data on the number of emergency vehicles to which the program would apply or the amount of funding available, which would influence the number of vehicles that could be retrofitted. In addition, data would have to be collected to determine the emission inventory of emergency vehicles, which is not presently available.

Approximate Cost To Businesses, State and Local Agencies

This strategy assumes that funding can be secured through the state to off-set the costs of retrofitting equipment. A current program for reducing NOx emissions, the Carl Moyer Program, has been funded at $19 to 25 million per year, which may increase in the coming year. Carl Moyer Program funds could be used for this measure, especially if the program is expanded to include the goal of reducing diesel PM, as recommended by the Advisory Committee (Carl Moyer Program Advisory Board 2000).

Potential Adverse Environmental Impacts

Installation of pollution control technologies, particularly diesel particulate filters, would improve the working environment of fire fighters and other emergency personnel who work in and around uncontrolled diesel engines. However, there are adverse environmental impacts associated with the application of catalyst-based DPFs. First, as is the case with most processes that incorporate catalytic oxidation, the formation of sulfates increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reductions in soluble organic fraction (SOF) emissions. Using diesel fuel with a very low sulfur content can minimize this effect.

In addition, the determination of whether or not a used DPF would be considered a “hazardous waste” at the end of its useful life depends on the material(s) used in the catalytic coating. DPFs can be manufactured with catalytic coatings such that the product would not be considered a hazardous waste at the end of its useful life.

DPFs are somewhat similar to automotive catalytic converters, and the California Department of Toxic Substances Control currently regulates used automotive catalytic converters as scrap metal as long as the catalyst material is left in the converter shell during collection and transport and the converters are going for recycling. The ash residue associated with cleaning a DPF would need to be tested before a hazardous waste determination could be made.

Older School Bus Replacement Program

Description of the Proposed Strategy

The California budget for 2000/2001 includes $50 million for use in the Older School Bus Replacement Program, which would provide funds to replace or retrofit old diesel school buses using cleaner technology. The ARB anticipates working with school districts, the Department of Education, the California Energy Commission, environmental organizations, manufacturers, and the public to develop an Older School Bus Replacement Program with maximum health and safety benefits. The overriding goal of the program is to reduce school children’s exposure to both cancer-causing and smog-forming pollution. Staff is aware that new school bus safety belt laws take effect in 2002. It is prudent that any funds used for new low emission school bus purchases should take advantage of the change in existing law to ensure that only the safest school buses are purchased.

Feasibility

The Older School Bus Replacement Program could include strategies for both purchase of new low emission buses, primarily compressed natural gas buses, and installation of PM retrofit devices on pre-1987 model year diesel buses. Through the public process for program development, staff can determine the extent to which funds are available for new bus purchases and/or retrofits. The adopted $50 million could fund the replacement of more than 400 new buses. With co-funding from the school districts and other clean air funding, the number of buses purchased could be substantially increased. In one air district program, school districts have been very innovative in securing fueling capabilities. There are additional advantages to the school districts when purchasing new buses, as the new buses comply with newer safety standards and districts would have reduced maintenance costs.

In some locations, PM retrofitting of school buses may be the most effective strategy because of cost, the non-availability of natural gas, lack of infrastructure, or other related factors. Retrofitting buses with particulate traps is much less expensive than buying a new bus. The cost of a retrofit kit would be up to $6000 each depending on volume. In addition, there will be an annual incremental cost of $100 for low-sulfur diesel fuel.

Estimated Emission Reduction

Staff was unable to estimate emission reductions for this report, but emission reductions will be estimated soon.

Cost to Businesses, State and Local Agencies

As an incentives program, the costs of the program would be primarily borne by the taxpayers of the State of California through the California budget.

Potential Adverse Environmental Impacts

This proposed measure would benefit California's environment and reduce the public's exposure to the toxic diesel PM after implementation. Reductions in HC and CO are also anticipated. However, there are adverse environmental impacts associated with the application of catalyst-based DPFs. First, as is the case with most processes that incorporate catalytic oxidation, the formation of sulfates increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reductions in soluble organic fraction (SOF) emissions. Using diesel fuel with a very low sulfur content can minimize this effect.

In addition, the determination of whether or not a used DPF would be considered a "hazardous waste" at the end of its useful life depends on the material(s) used in the catalytic coating. DPFs can be manufactured with catalytic coatings such that the product would not be considered a hazardous waste at the end of its useful life.

DPFs are somewhat similar to automotive catalytic converters, and the California Department of Toxic Substances Control currently regulates used automotive catalytic converters as scrap metal as long as the catalyst material is left in the converter shell during collection and transport and the converters are going for recycling. The ash residue associated with cleaning a DPF would need to be tested before a hazardous waste determination could be made.

Airport Ground Support Equipment Memorandum Of Understanding

Description of the Proposed Strategy

California has become one of the fastest growing air transportation links to the Pacific Rim, pushing California's average aviation growth even higher. As a result of this growth, airport-related activities account for an increasingly large component of the state's emissions inventory. Airport-related activities include aircraft engine emissions at landing and takeoff, on-road ground operations, such as taxis and shuttles, and airport ground support equipment, most of which consists of off-road equipment. A Memorandum of Understanding with airports and airlines operating in the South Coast Air Basin is currently being negotiated and will identify specific goals to achieve emission reductions from airport ground support equipment. The MOU is expected to significantly reduce emissions of hydrocarbons, oxides of nitrogen, and diesel PM.

The voluntary agreement negotiations were initiated through a public consultative process convened by the U.S. EPA to determine and evaluate opportunities for emission reductions specified for aircraft in the 1994 California Ozone State Implementation Plan (SIP). The consultative process identified airport ground support equipment (GSE) as one category that could achieve exhaust emissions below those required by regulation. Emission reductions are to be focused on the airports of the South Coast Air Basin. The primary stakeholders for the subcommittee on GSE are the U.S. EPA, Region IX, ARB, the South Coast Air Quality Management District, the Air Transport Association, the Federal Aviation Administration, the five major airports in the South Coast, and the major airlines serving those airports.

Feasibility

As a group, GSE largely comprise off-road types of equipment fueled by either gasoline or diesel. The negotiated voluntary agreement will focus on emission standards based on various strategies that can be applied to various pieces of equipment. One strategy for reducing emissions from GSE is to use alternative fuels that result in lower emissions operation. Alternatives to gasoline and diesel include liquefied petroleum gas (LPG or propane), compressed natural gas, and liquefied natural gas. Another strategy is to replace existing GSE with battery-powered or electric equipment. A third strategy is to repower GSE with new on-road engines which are currently certified to a more stringent emission standards than off-road engines. This allows the opportunity to generate additional emission reductions by using lower-emitting engines beyond what may be required for new purchase GSE. This opportunity will decrease, however, as new more stringent emission standards for off-road engines are phased-in.

Estimated Emission Reduction

Staff and the working group for the memorandum of understanding are in the process of calculating the estimated emission reduction from this measure.

Approximate Cost to Businesses, State and Local Agencies

Staff and the working group for the memorandum of understanding are in the process of determining the estimated costs of implementation.

Potential Adverse Environmental Impacts

No potential adverse environmental impacts have been identified for this measure to date. However, a more detailed evaluation of potential adverse environmental impacts will be done during the development of the specific control measures. Natural gas engines may have adverse effects different than diesel engines, i.e., increased emissions of formaldehyde.

Diesel Particulate Filters for Locomotives

Description of the Proposed Measure

The recently adopted U.S. EPA locomotive rule will result in significant reductions in diesel PM emissions from locomotives beginning with model year 2005. The national rule only affects PM emissions from model year 2005 and later locomotives and does not reduce PM emissions from older locomotives. Control of PM is expected to occur through improvements in air cooling, fuel management, combustion chamber configuration, and electronic controls. Diesel particulate filters, while mentioned in the regulatory support document accompanying the U.S. EPA rule, were not considered by the U.S. EPA for application by manufacturers to meet the standards. Because of recent developments in diesel particulate filter technology, however, retrofitting locomotive engines to further reduce diesel PM emissions could result in significant reductions in diesel PM emissions.

As discussed previously, the Clean Air Act preempts California from regulating emissions from new locomotives or new engines used in locomotive. Staff feels, however, that it would be valuable for locomotives to use aftertreatment technology to reduce particulate emissions. Staff suggests, therefore, exploring a voluntary program for locomotive retrofit with the railroads and working with the U.S. EPA to explore a future requirement that locomotives be retrofitted with diesel particulate filters achieving a minimum 85 percent efficiency.

Feasibility

Recent developments in diesel particulate filter technology suggest that a locomotive retrofit program may be feasible. Diesel particulate filters, along with other aftertreatment devices for reduction of PM and NOx emissions, require use of ultra-low-sulfur fuel for optimal efficiency. Any retrofit requirement, therefore, should be implemented along the same time frame as the availability of very low-sulfur fuel. While diesel particulate filters are not currently used on locomotives, these technologies, which are being developed for use with on-road heavy duty trucks, are expected to be applicable to locomotives.

Estimated Emission Reduction

Staff estimate the potential statewide emission reductions from retrofitting 90 percent of all locomotive engines operating in California by 2010 to be 862 tons per year, or a reduction of 75 percent of diesel PM, and 762 tons per year in 2020. Staff assumed that any emission control device would remove 85 percent of all diesel PM from exhaust.

Approximate Cost To Businesses, State and Local Agencies

A standard size for an older locomotive engine is approximately 3,500 horsepower. According to estimates by MECA (March 2000), the cost for retrofitting an engine of this size with a diesel particulate filter would range from $35,000 to $70,000. The costs of retrofitting could be offset by incentive funds, if available, such as the Carl Moyer Program.

Potential Adverse Environmental Impacts

No potential adverse environmental impacts have been identified for this measure to date. However, a more detailed evaluation of potential adverse environmental impacts will be done during the development of the specific control measures.

Particulate Matter Controls for Commercial Marine Vessels

Description of the Proposed Measure

Emissions from commercial marine vessels, which include cargo ships, tug and tow boats, fishing boats, cruise ships, and other large ocean-going ships, are a major source of diesel PM particularly in the South Coast Air Basin. Engine standards adopted by the U.S. EPA, however, only apply to new engines and do not impact emissions from existing ship engines. As discussed earlier, engine standards for commercial marine vessels are best approached at the national level by the U.S. EPA with state input.

Staff believes that a combination of voluntary, incentive, and regulatory approaches would significantly reduce diesel PM emissions from commercial marine engines. The following strategies are proposed: first, a voluntary speed reduction control strategy for ocean-going ships operating in California; second, a federal incentive program to provide funds, beyond those already available through California's funding of the Carl Moyer Program, for repowering with cleaner engines and for retrofitting existing engines; and third, a federal regulation that applies the new commercial marine engine standards to existing vessels when their engines are rebuilt or repowered. In addition to these engine strategies, a mandatory reduction in fuel sulfur level would also reduce emissions.

Feasibility

The technology for reducing stack emissions from ships is well known and increasingly being applied to new engines. While repowering old, dirty engines with new, current technology engines is feasible and produces significant emission reductions (SCAQMD 1998), new technologies are being developed that will result in even cleaner engines. For example, gas-turbine engines are lighter in weight and provide more horsepower per ton than diesel engines, although the higher initial cost and fuel consumption have limited their use (Aichele 2000a). Another promising technology is a smokeless diesel-propulsion system using common rail technology and water-jet injection that will equal the low emissions of the gas-turbine engine which is being developed by Wartsila NSD and Carnival Corporation. In addition to repowering, aftertreatment has also been demonstrated in ships (Aichele 2000b).

Estimated Emission Reduction

Staff requires additional data on the mix of specific programs that would be adopted to calculate estimated emission reductions. Staff did estimate, however, the emission reductions that could be achieved if 90 percent of existing commercial marine engines were retrofitted with emission control devices that remove 85 percent of diesel PM. Under this scenario, diesel PM emissions would be reduced statewide by 3,945 tons per year in 2010 and 4,504 tons per year in 2020. As an example of the emission reductions that could be achieved by repowering an individual vessel, the South Coast

AQMD reported reducing diesel PM by 0.81 tons per year from one tug boat by installing two new main engines and two new auxiliary engines (SCAQMD 1998).

Approximate Cost To Businesses, State and Local Agencies

In the above mentioned South Coast AQMD tug boat repower project, the cost was $390,000. In other projects completed with incentive funds costs ranged from $193,000 to 330,000 per boat. ARB staff have yet to estimate a cost per engine power for retrofitting boat engines. Incentive funds, if available, could be used to offset the costs of reducing diesel PM emissions.

Potential Adverse Environmental Impacts

No potential adverse environmental impacts have been identified for this measure to date. However, a more detailed evaluation of potential adverse environmental impacts will be done during the development of the specific control measures.

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